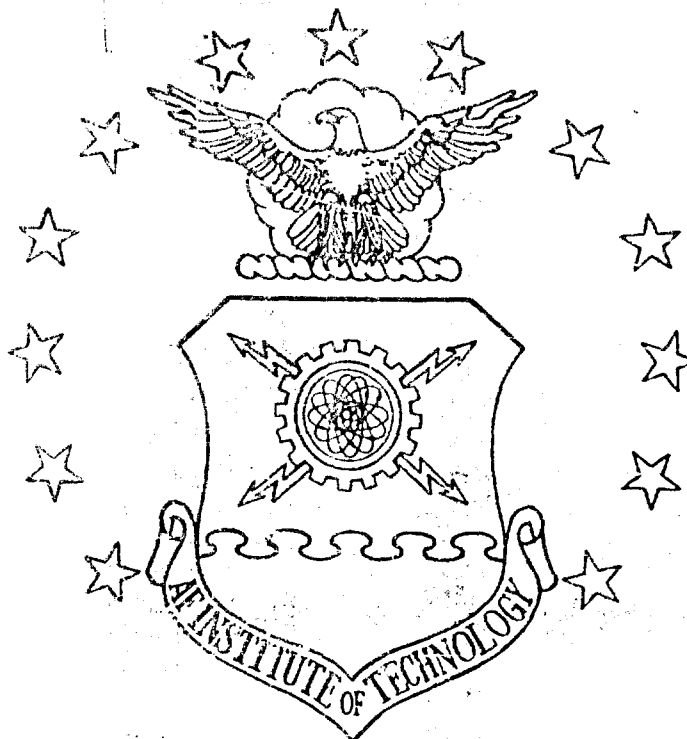
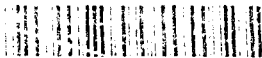


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A NETWORK FLOW AND GOAL PROGRAMMING
APPROACH TO MODELING THE IMPACT OF
PRE-ACCESSION TRAINING TO THE TRAINED
PERSONNEL REQUIREMENTS PROCESS

THESIS

William J. Beveridge, Captain, USAF

AFIT/GOR/ENS/91M-3

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91-05749



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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</small>				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE March 1991	3. REPORT TYPE AND DATES COVERED Master's Thesis		
4. TITLE AND SUBTITLE A Network Flow and Goal Programming Approach to Modeling the Impact of Pre-accession Training to the Trained Personnel Requirements Process		5. FUNDING NUMBERS		
6. AUTHOR(S) William J. Beveridge, Capt USAF				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Institute of Technology, WPAFB OH 45433-6583		8. PERFORMING ORGANIZATION REPORT NUMBER AFIT/GOR/ENS/91M-3		
9. SPONSORING MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSORING MONITORING AGENCY REPORT NUMBER		
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION AVAILABILITY STATEMENT APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) <p>2. HQ ATC was tasked to analyze the impact of pre-accession training to the Trained Personnel Required (TPR) and training production process. Pre-accession training is a policy of providing contracted initial skills training to enlistees prior to entering basic military training. The purpose of this study was to develop a method to model the impact of pre-accession training.</p> <p>A network modeling and goal programming approach was used. Comparisons between the current training policy and a pre-accession training policy were made. Sensitivity was conducted on the impact of a balk rate on the new policy. The balk rate is the percent of graduates of contract training who do not enter the Air Force.</p> <p>This study has shown that a policy of pre-accession training could be cost effective. The balk rate and subsistence package impact the savings over the current policy. The number of active duty personnel retraining in skills under this policy could also reduce the savings. Recruiting goals would have to be raised under the new policy. The quality of contract training or "blueness" of training were not factored into this model.</p>				
14. SUBJECT TERMS manpower training, network flow programming, goal programming, military technical training, TPR			15. NUMBER OF PAGES 82	
			15. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL	

AFIT/GOR/ENS/91M-3

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TO THE TRAINED PERSONNEL REQUIREMENTS PROCESS

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Operations Research

William J. Beveridge, B.A.
Captain, USAF

March 1991

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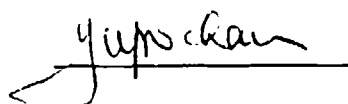
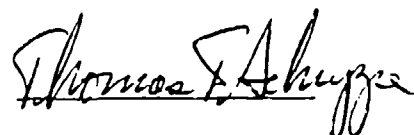
THESIS APPROVAL

STUDENT: Capt William J. Beveridge

CLASS: GOR91M

THESIS TITLE: A NETWORK FLOW AND GOAL PROGRAMMING APPROACH
TO MODELING THE IMPACT OF PRE-ACCESSION TRAINING
TO THE TRAINED PERSONNEL REQUIREMENTS PROCESS

DEFENSE DATE: 21 February 1991

COMMITTEE:	NAME/DEPARTMENT	SIGNATURE
Advisor	Dr Yupo Chan	
Reader	Col Thomas F. Schuppe/ENS	

Preface

The purpose of this study was to develop a model to measure impact of pre-accession training on the Trained Personnel Required (TPR) and training production process. A project of this size could not have been completed without the help of many people. I extend sincerest gratitude and appreciation to my advisor, Dr Yupo Chan. His vast technical expertise, encouragement, and patience kept me on track throughout this project. I am also indebted to Col Tom Schuppe whose comments ensured that all the pertinent information I knew made it into the text.

I would also like to thank Maj Dave Roberts and Capt Mark Emerson, from HQ ATC, for providing data and answering numerous questions. Without their help this research would not have been possible. Thanks also go to my friends and classmates for never letting a day go by without a good laugh. They made the "AFIT experience" a worthwhile one.

Finally, I would like to thank my wife Sandi for her support and patience during the many long nights put into this research. She was the key factor in the successful completion of this project.

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Abstract

HQ ATC was tasked to analyze the impact of pre-accession training to the Trained Personnel Required (TPR) and training production process. Pre-accession training is a policy of providing contracted initial skills training to enlistees prior to entering basic military training. The purpose of this study was to develop a method to model the impact of pre-accession training.

A network modeling and goal programming approach was used. Comparisons between the current training policy and a pre-accession training policy were made. Sensitivity was conducted on the impact of a balk rate on the new policy. The balk rate is the per cent of graduates of contract training who do not enter the Air Force.

This study has shown that a policy of pre-accession training could be cost effective. The balk rate and subsistence package impact the savings over the current policy. The number of active duty personnel retraining in skills under this policy could also reduce the savings. Recruiting goals would have to be raised under the new policy. The quality of contract training or "blueness" of training were not factored into this model.

A NETWORK FLOW AND GOAL PROGRAMMING APPROACH
TO MODELING THE IMPACT OF PRE-ACCESSION TRAINING
TO THE TRAINED PERSONNEL REQUIREMENTS PROCESS

I. Introduction

Background

The mission of the Air Force is to organize, train, and equip air forces for the conduct of prompt and sustained combat operations in the air. The enlisted force plays a critical role in carrying out that mission. Air Training Command (ATC) is responsible for recruiting and training Air Force enlisted personnel. The Trained Personnel Requirements (TPR) process analyzes Air Force training needs for a three year period. The process looks at the current year, the budget year, and the first planning year. The TPR process, set at the Training Flow Management Conference, is conducted every April and October. HQ USAF/DPPP manages the TPR process. Management control of training production is an ATC concern. The TPR is the total number of trained personnel required in each enlisted Air Force Specialty Code (AFSC). Table 1, on the following page, shows the total TPR for fiscal years 90, 91, and 92.

TABLE 1
TPR TOTALS FOR ALL SKILLS (7)

<u>FY</u>	<u>TOT TPR</u>	<u>TOT TECH</u>	<u>NPS</u>	<u>PS</u>	<u>RET</u>	<u>TOT OTH</u>
90	44700	38863	32758	7	6098	5837
91	38336	34213	29187	0	5026	4123
92	36821	33127	29435	0	3692	3694

The total TPR is made up of the total number of enlisted personnel required to go to technical training (TOT TECH). This includes non-prior service (NPS), prior service (PS), and active duty retrainees (RET). Also included are others not required to go to formal technical training (TOT OTH). This group includes directed duty assignments, OJT retraining, and bypass personnel. This research is concerned with the TOT TECH category only.

ATC has found TPR changes dramatically before and during the fiscal year. Planning for training has become more difficult. The "text book" method is to build a plan based on the projected mission and requirements. A program is built based on the force structure needed for the plan. Dollars are then budgeted based on the program. However, the "school of hardknocks" tells us that dollars are appropriated without regard to the mission or requirements. A program is built to fit the dollars. Then an assessment of impact on the plan is made. The Air Force is now in an era of decreasing TPR. Budget pressures

are forcing manning drawdowns and subsequent accession cuts (10). In addition, budget cutbacks are forcing base closures which include ATC operations at Chanute AFB and Mather AFB (7). In response to this, a small think tank called the Northern National Education Foundation designed a new system for training enlisted personnel called Technical Training, Pre-enlistment Opportunities (TECH/Pro). The proposal called for military technical training courses that have generic civilian equivalent courses to be contracted out. This proposal drove the Government Accounting Office (GAO) to study the feasibility of conducting military technical training at civilian institutions. The ATC commander directed a study group to analyze the impact of this proposal to the TPR and training production process (23).

Current System. Currently, an enlistee can spend up to twelve months in the Delayed Enlistment Program (DEP) before reporting to Basic Military Training (BMT). Upon completing the six week BMT course, an enlistee can be sent directly to an operational unit for on-the-job training or to a military technical training center for specialized training. Figure 1, on the following page, illustrates the current training policy.

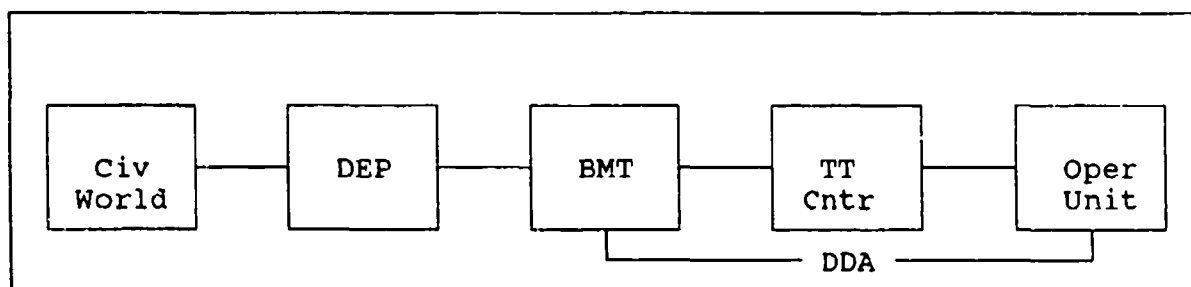


Figure 1. Current Training Policy

Table 2 illustrates the number of personnel processed through the system during the last three fiscal years.

TABLE 2
PERSONNEL PROCESSED THROUGH
CURRENT SYSTEM FY88-FY90 (10)

	<u>FY88</u>	<u>FY89</u>	<u>FY90</u>
<u>DEP</u>			
TOTAL POOL	77601	80175	60398
TOTAL LOSS	8346	7459	6865
%	10.8	9.3	11.4
<u>BMT</u>			
TOTAL ENLISTED	41200	43450	36000
TOTAL DISCHARGED	2620	3185	2642
%	6.4	7.3	7.3
<u>TT</u>			
TOTAL ENTERED	35616	36153	**
TOTAL ELIMINATED	1695	1552	
%	4.8	4.3	
** Data not currently available			

The cost for an individual to make it through the system is given in Table 3.

TABLE 3
ACQUISITION VARIABLE COST
PER RECRUIT IN FY90 DOLLARS (11)

Recruiting	\$ 2,993
Travel	\$ 382
Clothing	\$ 703
BMT Cost	\$ 3,066
<u>Tech Training</u>	<u>\$ 8,300</u>
Total	\$15,444

The cost of technical training is based on an average course length of 11.86 weeks. A \$1,300/month cost is associated with pay and allowances, the approximate cost of tuition alone would be \$4,700 per student (11; 21).

Proposed System. Pre-accession training is the initial skills technical training an enlistee would receive prior to BMT. The training would prepare an enlistee to perform a job at an operational unit. While in the DEP, an enlistee would receive specialized training from a contracted source before entering BMT. After BMT, the enlistee would be sent directly to an operational unit. Figure 2, on the following page, illustrates the proposed system.

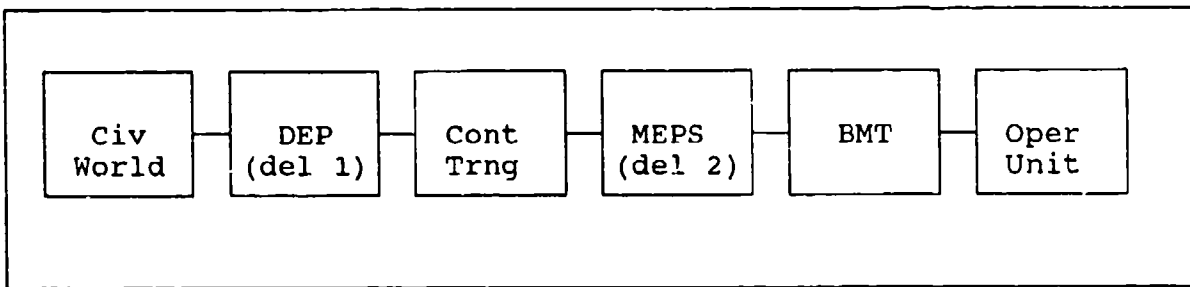


Figure 2. Pre-accession Training Policy

As in the current system, an enlistee can spend up to twelve months in DEP before attending a training course, upon completion of a course, the enlistee could be delayed an additional four weeks before reporting to a Military Entrance Processing Station (MEPS) and proceeding to BMT. ATC expects contract training to be 80% of the tuition cost of military training. In addition, active duty pay does not start until BMT. A student in contract training could be paid a subsistence allowance of up to \$700 per month (22). This allowance would include a small stipend plus \$300 per month for contract housing. This would be a considerable savings over the \$1300 per month for pay and allowances currently associated with military technical training. Attrition rates for initial DEP, BMT, and technical training are expected to be the same as the current system. However, a problem exists during the second delay after completion of contracted technical training. An unknown balk rate exists during the additional delay. The balk rate is the percent of individuals who decide not to go to BMT after successfully completing technical training. The rate could be as low as five

percent or even as high as fifty percent (although this is highly unlikely) (21).

Issues. In addition to the unknown balk rate, other concerns are raised about the impact of pre-accession training. The Guaranteed Training Enlistment Program (GTEP) is a program that guarantees an enlistee a specific type of training and AFSC upon entering the Air Force. Errors in production can increase as the lead time from AFSC classification to BMT and first assignment increases. The training demand process is adaptive. Training production can be lowered or raised as TPR is lowered or raised as long as the course start date can be met. The GTEP hinders management control of training production. Currently, few enlistees are in the GTEP. However, pre-accession training would force all enlistees to be in GTEP and could further aggravate the management control problem (10; 21). The impact of a pre-accession training policy to recruiting goals is also unknown. In addition, the quality of training and "blueness" of the training are unknown. The "blueness" factor is the development of military qualities, such as adherence to military standards, self discipline, and physical conditioning a student would receive at a military technical training center (21).

Problem Statement

HQ ATC has been tasked to identify critical factors and minimize costs associated with options for conducting USAF initial skills training. HQ ATC needs an effective model to simulate the uncertainty in the Training Personnel Requirements

(TPR) process. The objective of this research is to model the impact of pre-accession training on the TPR and training production processes. The model should compare the current training policy with a policy that includes pre-accession training. The model should have the flexibility to accommodate policy changes affecting the processes (21).

Sub-objectives. To accomplish the research, the following objectives must be met:

1. Determine specific output requirements needed by HQ ATC;
2. Identify which training courses should be modeled;
3. Determine the number of graduates produced for a fiscal year;
4. Identify surplus/shortage of personnel for a given course;
5. Determine cost of pre-accession training;
6. Determine the impact of rising balk rates on the model.

II. Literature Review

Review of Methodologies Applicable to Modeling Personnel Problems

There are various methodologies available for use in modeling personnel problems. Jameson found in her thesis research applicable methods fall into the following categories:

1. Simulation methods
 - a. Entity flow simulations
 - b. System dynamics simulations
2. Analytic methods
 - a. Probabilistic models
 - b. Linear programming models
 - c. Network flow programming models (12:9).

Not all methods lend themselves readily to meeting the research goals of this project.

Specific output requirements for the project will be determined during interviews with knowledgeable individuals from HQ ATC/CSY. In addition, which training courses should be used for the model can also be identified during interviews with ATC personnel. Data is available on 32 enlisted specialty codes.

Charpie effectively used entity flow simulations in his study of B-52 radar navigators (6:13). However, entity flow approaches in the past have proved to be ineffective in evaluating the effects of policy changes (12:10-11).

According to two previous thesis efforts, the system dynamics approach has been used to evaluate the effects of policy changes on personnel problems in the past. System dynamics models use feedback loops to simulate real world interactions, thereby effectively testing the impact of policy changes. Jameson and Olson found that Clark and Lawson used a system dynamics simulation to model the impact of policy changes on a segment of Air Force enlisted personnel subject to a high number of overseas rotations (12:11-12; 18:16). The system dynamics approach could be used to determine the impact of policy changes on management control of the TPR process.

Probabilistic models, such as Markov models, alone would be inappropriate for this project. Zanakis and Maret stated that Markov models do not "consider costs, restrictions, and conflicting objectives that exist in a real world situation" (26:55). Markov techniques could be used with linear programming techniques to build a more realistic model.

Linear programming has been used on many occasions to model personnel problems. Goal programming is an extension of linear programming. Traditional linear programming optimizes a single objective. On the other hand, goal programming satisfies multiple objectives. Zanakis and Maret used goal programming to project the number of engineers needed by a chemical company. They also used goal programming to evaluate various management policies (26:61).

Network flow models are closely related to linear

programming models. Network flow models can be solved more efficiently. Personnel problems can be solved readily by network flow models.

The combination of goal programming and network flow programming can be used to identify the surplus/shortage of trained personnel, determine the cost of pre-accession training, and determine the average time of an enlistee in the DEP.

The initial search for methodologies to model the impact of pre-accession training on the TPR process revealed numerous options. The following paragraphs will look at literature applicable to this research proposal. A discussion of analytical methods will be addressed. The specific topics of uncertainty, goal programming approaches, and network flow approaches will be covered.

Uncertainty. Uncertainty is a lack of confidence in something. Uncertainty often interferes with decision-making. Battilega and Grange state "virtually every problem related to military analysis carries with it some element of uncertainty and randomness" (2:28). The management of training production under a pre-accession training option is no exception to the rule.

Uncertainty can be dealt with directly or indirectly. Statistical methods are used to directly deal with uncertainty. Random events which occur in a problem are explicitly represented in statistical methods. On the other hand, indirect treatment of uncertainty is handled by probabilistic methods. In probabilistic methods, random events are less explicitly

represented. Usually, the mean or average value of a random variable is used to model the problem. Probabilistic methods are generally considered easier to do and understand than statistical methods (2:28-31).

Dixon examined the problem of representing uncertainty in models in his comparative analysis of three models developed for acid-rain assessment. He states that uncertainty "may be due to unpredictable human factors, imprecision of measuring instruments, poor records of past experience, lack of understanding of certain processes, or many other reasons" (9:29). Sometimes uncertainty is small and has little effect on the outcome of analysis of a problem. Other times, uncertainty is so extreme the question of how to model problems of this nature is relevant.

The strengths and weaknesses of the methods of representing uncertainty in the models were addressed by Dixon. The scope of the uncertainty representation, source of model inputs, and techniques for combining probabilities were discussed. Uncertainty about interrelationships and uncertainty about variable values were the two representation types used in the models. Dixon considered the representation of uncertainty about variable values to be a weakness of all three models.

Model inputs were of the subjective view or objective view of probability. The subjective approach allows the analyst to input the probabilities on model variables. The objective approach lets the analyst predetermine the probabilistic

representation of inputs. The strength of the subjective approach is the ability to experiment and investigate the consequences of a range of possible inputs. However, the problem of how, and from where, the most reliable inputs might be obtained arises. The objective approach relieves the analyst of this burden but does not allow for experimentation.

The combining of probabilities was done using either Monte Carlo simulation or a decision-tree. Monte Carlo simulation is a method that uses random sampling techniques to get approximate solutions to a problem. A range of values, each with a probability of being the correct solution, is given. A decision-tree is a method of counting each of the possible decisions that can be made and each of the possible outcomes that can occur based on those decisions. The strength of Monte Carlo simulation is the ability to combine numerous probability distributions within realistic time constraints. The complexity of calculations increases linearly with the number of variables in Monte Carlo simulations. The complexity of calculations increases exponentially with the number of variables in decision-tree models. One weakness of Monte Carlo simulation is the occurrence of significant variance between results of successive runs of the model. Another weakness is the "large increase in complexity of calculations required to reflect dependencies between input distributions" (9:35-37).

The following questions about developing models in situations of uncertainty were raised by Dixon:

1. How should the model be structured, what elements of the problem are important enough for inclusion, and how are the interrelationships defined?

2. Is the danger of modeling under uncertainty twofold: that of producing results which, if verifiable, would prove highly inaccurate, and that of undue reliability attributed to misleading results, since the analytic approach inspires confidence?

3. Does model accuracy increase with greater inclusion of detail?

4. Is there an optimal minimizing balance between model unreliability caused by oversimplification and unreliability caused by the inclusion of detail despite uncertainty about its role?

5. Where is uncertainty to be represented explicitly, and how should this be done?

6. Which problem elements are represented as uncertain, what form should the elements be, and how should these uncertainties be combined (9:38)?

Lindley claims that "probability is the only sensible description of uncertainty" (16:1). Kohlas presents a new approach for the representation and analysis of uncertainty. Uncertainty is described by belief functions instead of probability distributions. A belief function is the summation of the probabilities that an unknown variable X takes a value in

some arbitrary interval $[r,s]$. The interval is set by one or more oracles (e.g. an expert, a forecasting procedure, sources of evidence, etc.). The probability that X takes a value in the interval is then assigned. A Monte Carlo method is then applied for the computation of belief (14:378-381).

Kohlas compared two techniques currently used to cope with uncertainty with the belief function approach. In the first technique, a few possible and reasonable values for each uncertain input variable are selected and evaluated. A drawback to this approach is the number of combinations grow very fast. It is practically impossible to evaluate all possible combinations. Therefore, the analyst must choose small numbers of possible value combinations and limit the model evaluation to them. This introduces certain arbitrariness into the analysis. A second technique is modeling uncertain input variables as random variables with some given probability distributions. This technique avoids the problems described in the first technique. However, the problem of how to express the available knowledge about the possible and probable values of these input variables arises. The main problem is modeling this knowledge correctly and consistently. The model must incorporate highly subjective judgements (14:378).

The use of belief functions provides better incorporation of subjective judgments concerning input variables and the relationship between variables. It allows for the combination of evidence from different sources, the modeling of partial

knowledge, and the inclusion of contradicting evidence. The new approach "allows a much more realistic and flexible description of knowledge, opinions, judgments and evidence" (14:377).

Goal Programming Techniques. Goal programming (GP) is a linear programming technique for optimizing a problem with multiple objectives. Goal programming techniques have been used to solve numerous manpower problems. Figure 3 illustrates a generic GP formulation.

$$\begin{aligned} & \text{Min } \sum_{i=1}^m (d_i^- + d_i^+) \\ & \text{s.t. } Ax + Id^- - Id^+ = b \\ & \quad Bx \leq h \\ & \quad x, d^-, d^+ \geq 0 \end{aligned}$$

where d_i^- and d_i^+ represent the negative and positive deviations from m goals

b is a column vector for m goals

x represents the number of personnel

$Bx \leq h$ are additional constraints placed on the model

Figure 3. Generic GP Formulation (15:39-41)

Goal programming models have been developed to deal with the multiple objectives driving personnel planning. The objective function used in goal programming models "weights the importance of various constraints and sub-objectives according to priorities expressed by one or several decision-makers" (17:187). Martel and Price have found results of goal programming models to be good, despite the lack of theoretical justification for the way

objective function weights are obtained.

Goal programming is appropriate in manpower planning cases where information on manpower supply, budget, demand, etc., is fixed. For manpower planning problems under uncertainty, Martel and Price suggest using a dynamic stochastic programming approach. This approach was used to solve a manpower planning problem for officers of the Canadian Armed Forces (17:193).

Sengupta also addressed goal programming under uncertainty. A typical goal programming model could be:

$$\begin{aligned} \min & \sum_{k=1}^K (d_k^+ + d_k^-) \\ \text{s.t.} & \sum_{j=1}^n c_{kj} x_j - (d_k^+ - d_k^-) = g_k; \quad k=1,2,\dots,K \\ & \sum_{j=1}^n a_{ij} x_j \leq b_i, \quad i=1,\dots,m \\ & d_k^+, d_k^-, x_j \geq 0, \quad j=1,\dots,n \end{aligned}$$

where g_k represents k TPR goals, and d_k^+ and d_k^- represent positive and negative deviations from the goals.

He found "stochastic goal programming may also be formulated when the deviations can be probabilistically interpreted"

(24:50). Let $g_k = \sum_{j=1}^n c_{jk} x_j + e_k$, where e_k is the error which is known to be normally distributed with mean zero and variance unity for each k (e.g. TPR goals that fluctuate up and down).

Then the objective function becomes:

$$\min E[\sum_{k=1}^K d_k]$$

Zanakis and Maret used another variation by combining Markov processes with goal programming. Markov processes have been used since the early sixties to model manpower planning problems. Markov processes enable the analyst to predict the number of

personnel gains and losses in future years based on a given policy for hiring, promotion, dismissal, etc.. However, Markov processes cannot consider costs, restrictions, and conflicting objectives that exist in real world situations. Therefore, Markov processes were combined with goal programming to solve planning problems under various restrictions and conflicting objectives. This approach provides versatility in handling multiple conflicting goals common in real world planning (26:55-56).

Aronson and Thompson applied the forward simplex method to multiperiod personnel planning goal programming models. The forward simplex method is "an adaption of the ordinary simplex method used for solving general multiperiod linear programs" (1:129). The general step in the method is to find the solution to the T period problem by augmenting the solution to the T-1 period problem. Aronson and Thompson applied the method to a goal programming personnel planning model dealing with recruiting requirements for a large naval laboratory. The method proved to be more efficient than conventional LP methods (1:130-132).

Network Flow Programming Techniques. Network flow techniques follow many of the general rules found in goal programming techniques. However, network flow techniques are usually more efficient. A network is a collection of nodes which are connected by arcs. It is easy to visualize a manpower system as a network. The nodes of the network represent the states of the manpower system at some time T. The arcs represent hires,

promotions, and staying in the same state (19:1233-1234).

Price used network flow techniques to solve manpower problems that are often modeled using goal programming techniques. He modeled a military manpower system consisting of 28 classifications, four ranks in each classification, and three "general service" ranks. When modeled using goal programming, over 600 constraints and over 1250 variables were needed. The same model using network flow programming had fewer than 400 nodes and fewer than 1200 arcs (19:1239). Solving manpower problems with network flow techniques proved to be more efficient than solving the same problem with goal programming techniques.

Price and Gravel provide a method for solving network problems with side constraints. Side constraints are those constraints that are not inherently modeled within the network. Constraints that might be modeled within the network are upper and lower bounds on arc flow. Standard network constraints such as conservation of flow (e.g. flow into a network equals flow out of a network) would also be modeled within the network. On the other hand, side constraints could include the effects of attrition on the network and/or the impact of budgetary limits on the network (20:198-202).

Charpie used network flow programming in analyzing personnel shortages in the B-52 radar navigator career field. He examined changes occurring in the crew force. This included reductions of B-52 crew force to man the B1-B, reductions in staff positions, changes in the policy of allowing crew members to go to career

broadening positions, and decreases in retention rates. A cross-sectional network model was used. The model traces the netflow throughout the network without regard to time spent in a given state. However, this model could not be applied to a system in which the length of time spent in a state affects the outcome. In addition, the model is not an optimization technique (6:13-26).

Summary

The literature review provided a discussion of topics pertinent to the problem of modeling the impact of pre-accession training on the TPR and training production process. Coping with the effects of uncertainty will be an underlying concern throughout the research effort. Goal programming techniques, when combined with other techniques, can be a successful part of the overall approach to meeting the research objectives. Network flow techniques that incorporate some aspects of goal programming will also be an effective tool in solving the research problem.

III. Methodology

General Approach

The purpose of this chapter is to discuss the methodology selected to model the impact of pre-accession training on the TPR and training production processes. Since TPR goals are established in advance, goal programming (GP) would appear to be an appropriate solution technique. GP adds flexibility and realism to the model. GP can be used to look at deviations in the required number of personnel trained and the actual number trained. However, GP alone cannot deal with the costs associated with the change in training policy.

Multicommodity Network Flow. The flow of personnel through the training process can be modeled using network flow programming. A general network model consists of nodes which are connected by arcs. The nodes of the network represent the state of an enlistee at any given point in time. Example states could include: Delayed Enlistment Program (DEP); Basic Military Training (BMT); or Technical Training (TT). Flow along the arcs represents the movement of an enlistee through the network. The flow between the nodes represents an assignment path which connects the nodes. Figure 4, on the following page, illustrates the network representation of the current training policy.

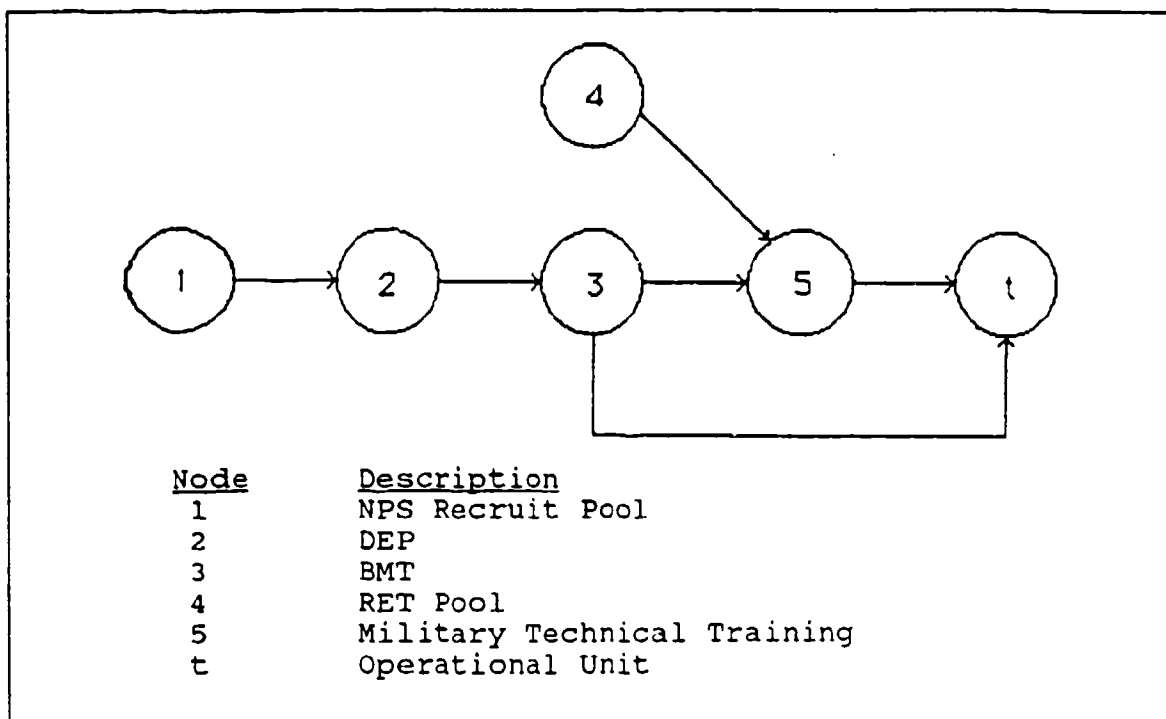


Figure 4. Network Representation of Current Training Policy

The arc connecting node 3 to node t represents the 2.6% of enlistees that bypass technical training and go directly to an operational unit. Figure 5, on the following page, illustrates a network representation of a pre-accession training policy.

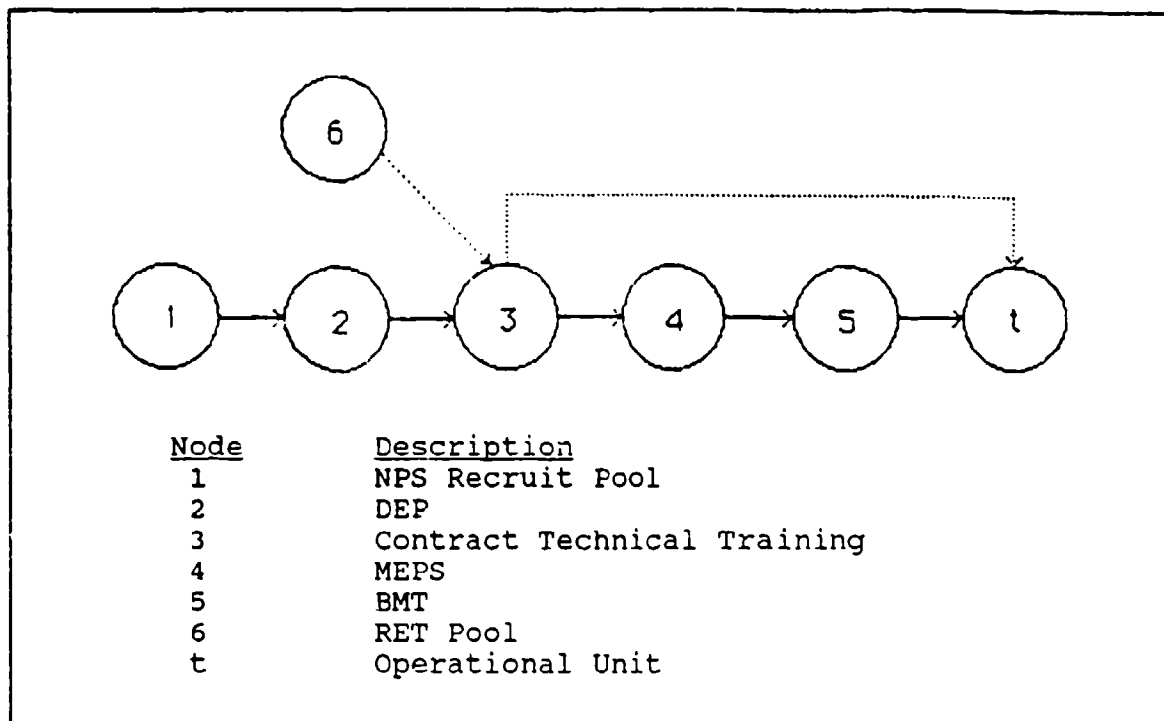


Figure 5. Network Representation of Pre-accession Training Policy

The dotted line connecting node 3 to node t represents the fact that active duty retrainees go directly back to an operational unit after completing contract technical training.

Multicommodity network flow techniques are used when it is necessary to distinguish among the units that flow in the network (3:587). Figure 6, on the following page, illustrates a multicommodity minimal cost flow (MMCF) formulation.

$$\begin{aligned}
& \min \sum_{k,m} c_m^k x_m^k \\
& \text{s.t. } \sum_{e_m \in A_n} x_m^k - \sum_{e_m \in B_n} x_m^k = \begin{cases} S_k, & \text{if } n=s_k \\ -S_k, & \text{if } n=t_k \\ 0, & \text{otherwise} \end{cases} \\
& \sum_k x_m^k \leq b_m, \text{ all } m \\
& 0 \leq x_m^k \leq u_m^k, \text{ all } m, k
\end{aligned}$$

where k = commodities

m = arcs

c_m^k = the unit cost of commodity k in arc m

x_m^k = the flow of commodity k in arc m

b_m = capacity of arc m

u_m^k = upper bound on commodity k in arc m

$e_m \in A_n$ represents arcs originating at node n

$e_m \in B_n$ represents arcs terminating at node n

s_k = source

t_k = sink

Figure 6. Multicommodity Minimal Cost Flow (13:209-210)

An MMCF network, combined with GP techniques was used to solve the problem in this thesis. Figure 7, on the following page, illustrates the network modeled for this research.

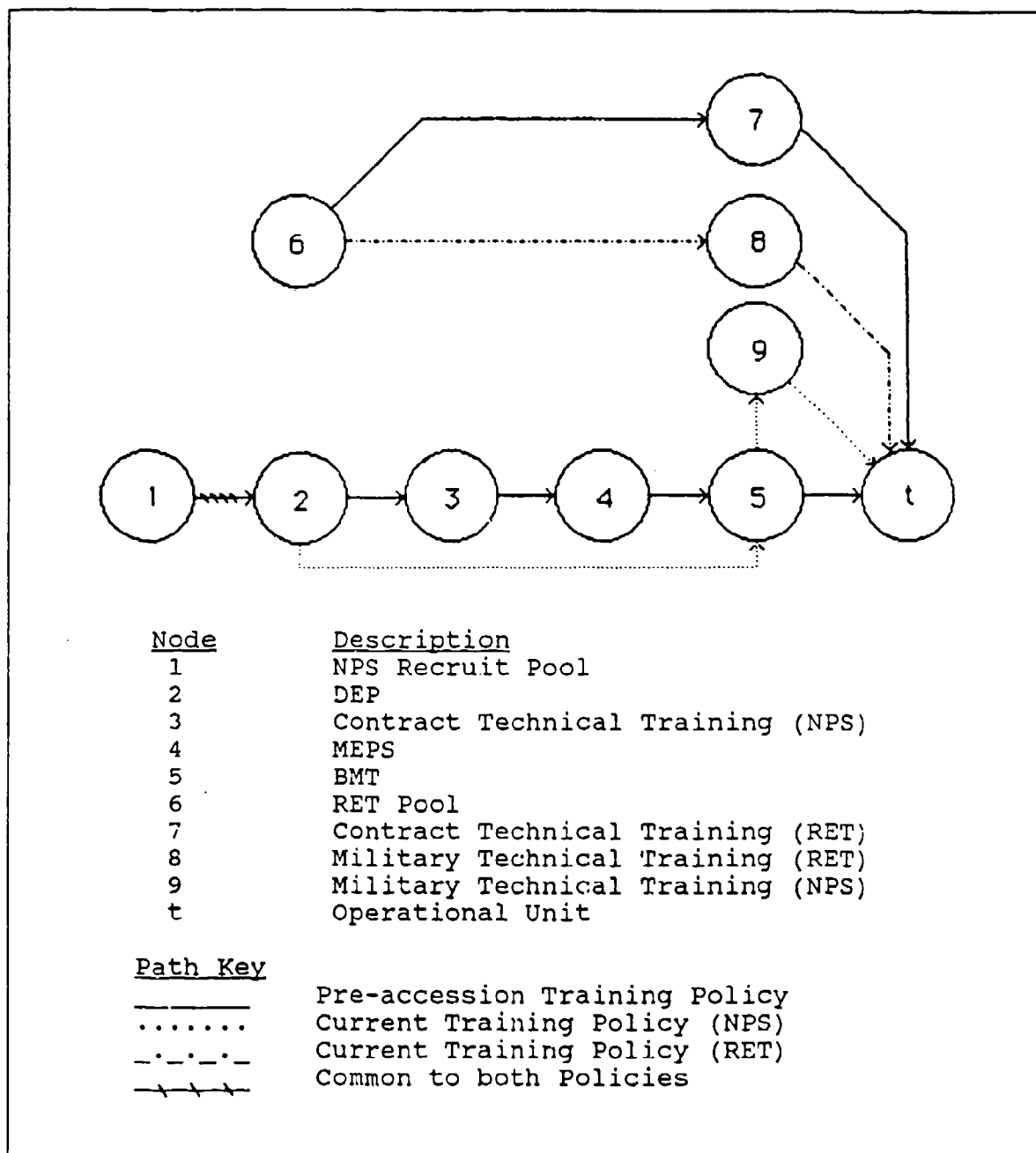


Figure 7. Network Representation of Combined Training Policy

Model Structure

The approach used to formulate the model included the following:

1. Identify the decision variables;
2. Identify the constraint set;
3. Identify the data necessary to quantify the constraints;
4. Formulate the constraint set;
5. Formulate the objective functions.

Decision Variable Identification. Identification of the decision variables for this problem is straight forward. Thirty-two courses representing thirty-two Air Force Specialty Codes (AFSCs) were available for use in this study. The number of trainees in each of these AFSCs represent the decision variables. Appendix A is a list of the AFSCs and corresponding fiscal year 1991 TPR goals.

Constraint Set Identification. Constraints pertaining to the problem of conducting training were placed in several categories. Constraints that influence how many enlistees will be trained in each AFSC for each fiscal year fall under the categories of TPR goal constraints, attrition constraints, and accession constraints. The TPR for each AFSC, attrition rates, and course length can influence the cost of production. In addition, zero-one switch constraints were used in the model.

Data Identification. The following input data has been provided by ATC:

1. Course identification numbers by AFSC;
2. Course length;
3. Variable costs of each course;

4. Course attrition rates;
5. DEP attrition rates;
6. BMT attrition rates;
7. TPR values.

Constraint Set Formulation. Decision variables will be represented generically by

$$x_{ij}$$

where: i = originating node

j = terminating node

x = number of personnel in the network

$$x_{ij} \geq 0.$$

Table 4, on the following page, is presented to provide references for indices, technological coefficients, and constants used.

TABLE 4
INDICES, TECHNOLOGICAL COEFFICIENTS,
AND CONSTANTS SYMBOLOGY

<u>INDEX</u>	<u>DEFINITION</u>
s	source
t	sink
i	originating node
j	terminating node
k	commodity
m	arc
<u>TECHNOLOGICAL COEFFICIENTS</u>	
c	training cost
s	pay and allowances/subsistence
cl	class size
a _{ij}	attrition rates
br	balk rate
<u>CONSTANTS</u>	
TPR _k	trained personnel required for AFSC _k
ACC _k	accessions per AFSC _k

TPR Goal Constraints. The TPR goal constraints represent the total formal technical training production requirements for non-prior service (NPS) enlistees and active duty retrainees (RET). The following generic formulations represent the constraint:

$$\sum_i x_{it}^k = \text{TPR}_k$$

$$\sum_i x_{it}^k + d_k^- - d_k^+ = \text{TPR}_k$$

$$\sum_i x_{it}^k \leq \text{TPR}_k(\text{NPS})$$

$$\sum_i x_{it}^k \leq \text{TPR}_k(\text{RET})$$

where, d_k^- = the negative deviation from TPR_k

d_k^+ = the positive deviation from TPR_k

Attrition Constraints. Attrition constraints include DEP losses, BMT discharges, and technical training (TT) eliminations. Also included is the balk rate associated with the second delay in the pre-accession training policy. A generic formulation of an attrition constraint would be:

$$\sum_i x_{ij}^k - \sum_i (1-a_{ij}) x_{i-1,i}^k = 0$$

Several assumptions were used in the attrition constraints. DEP, BMT, and TT attrition rates for a policy of pre-accession training are comparable to the current system. Balk rates were to be tested, at five percent increments, from ten to fifty percent.

Accession Constraints. Accession constraints represent the restriction on the number of NPS enlistees entering BMT. The generic formulation would be:

$$\sum_i x_{ij}^k \leq ACC_k$$

Switch Constraints. Zero-one variables were used as switches to select the most efficient path to take through the network. The variable y_{ij} was set to zero if the arc between two nodes was not taken or set to one if the arc was chosen. A detailed explanation of the use of switches is given in the next chapter.

Objective Function Formulation. The following objective function was formulated for the network model:

$$\min \sum c_m^k x_m^k$$

where c_m^k = training cost of traveling along arc m

x_m^k = the flow of personnel in arc m

for the GP model the following formulation was used:

$$\min \Sigma (d_k^- + d_k^+)$$

where d_k^- = the negative deviation of training AFSC_k

d_k^+ = the positive deviation of training AFSC_k

Output Requirements. A set of comparisons between pre-accession training and the status quo will be made. Comparisons between the network model and the GP model will be made. The number of trained personnel and surplus/shortages will be identified. The costs associated with training under varying balt rates and subsistence options will be provided.

Summary

This chapter presented a general model for representing the impact of pre-accession training on the TPR and training production processes. A brief discussion of input and output requirements was given. The next chapter presents a illustrative example and analysis of the problem.

IV. Illustrative Example and Analysis

Illustrative Example

This chapter presents the results of an illustrative example of the network model and goal programming model discussed in the previous chapter. The objective is to determine how increasing balk rates affect the cost of training and the ability to meet TPR goals under a policy of pre-accession training. The examples were processed on the linear optimization package QSB (5). As stated in the last chapter, the approach used to formulate the example was: 1) identify decision variables; 2) identify the constraint set; 3) identify the data necessary to quantify the constraints; 4) formulate the constraint set; and 5) formulate the objective functions.

Decision Variable Identification. The following AFSCs are represented: 1) 23131, Graphics Specialist; 2) 45234A, Apprentice Tactical Aircraft Maintenance Specialist; 3) 45430A, Apprentice Aerospace Maintenance Specialist; 4) 45730A, Apprentice Strategic Aircraft Maintenance Specialist; 5) 49131, Apprentice Communications-Computer System Specialist; 6) 54531, Apprentice Liquid Fuels System Specialist; 7) 67231, Financial Management Specialist; 8) 90430, Cardiopulmonary Lab Specialist; 9) 91330, Apprentice Physical Therapist; and 10) 98130, Dental Assistant Specialist.

Constraint Set Identification. The following set of constraints will be used: 1) TPR goal constraints; 2) attrition

constraints; 3) accession constraints; and 4) switch constraints.

Data Identification. Table 5 contains the AFSC TPR goal and course attrition data used for the example.

TABLE 5
TPR AND ATTRITION DATA FOR ILLUSTRATIVE EXAMPLE

AFSC	Attrition Rate (%)	FY91 TPR GOALS		
		NPS	RET	TOT
23131	3.4	8	0	8
45234A	3.8	554	0	554
45430A	1.4	750	0	750
45730A	10.0	75	0	75
49131	1.9	434	125	559
54531	1.1	40	0	40
67231	0.8	82	7	89
90430	9.4	41	20	61
91330	6.7	22	30	52
98130	3.8	239	90	329

Cost data for each AFSC was based on a tuition rate of \$4,700 per month plus \$1,300 pay and allowances per month for the current training policy. For a policy of pre-accession training, tuition was 80% of the current tuition, a cost of \$3,750 per month. In addition, a stipend and housing allowance can be provided. The example was run using a \$300 per month housing allowance with a \$150 per month stipend and also with a \$300 per month stipend. Retrainees would continue to receive \$1,300 per month pay and allowances under a pre-accession policy. Table 6, on the following page, presents cost data for military training (MT), contract training for non-prior service (CT(NPS)), and contract training for retrainees (CT(RET)) used in the example. All

costs include pay/stipend/housing allowances.

TABLE 6
COST DATA FOR ILLUSTRATIVE EXAMPLE

AFSC	Course Length (wks)	MT	\$150 Stipend CT(NPS)	\$300 Stipend CT(NPS)	CT(RET)
23131	11.4	8150	4950	5340	7200
45234	8.0	7120	4585	4865	6170
45430	9.6	7600	4750	5090	6650
45730	8.0	7120	4580	4865	6170
49131	7.6	7000	4550	4810	6050
54531	7.6	7000	4550	4810	6050
67231	9.8	7650	4775	4775	6700
90430	11.4	8150	4950	5340	7200
91330	9.6	7600	4750	5090	6650
98130	9.6	7600	4750	5090	6650

Additional data for recruiting, travel, and BMT costs identified in Chapter I were also used.

Constraint Formulations. Decision variables for constraint formulation will be represented by

$$x_{ij}^k,$$

where i = originating node
j = terminating node
 $x_{ij} \geq 0$

k: a = 23131
b = 45234A
c = 45430A
d = 45730A
e = 49131
f = 54531
g = 67231
h = 90430
i = 91330
j = 98130

and

$$y_{ij},$$

where i = originating node

j = terminating node
 $y_{ij} = 0, 1$

TPR Goal Constraints. The following TPR goal constraint equations were used in the network models.

$$\begin{aligned}
 x_{5t}^a + x_{7t}^a + x_{8t}^a + x_{9t}^a &= 8 \\
 x_{5t}^b + x_{7t}^b + x_{8t}^b + x_{9t}^b &= 554 \\
 x_{5t}^c + x_{7t}^c + x_{8t}^c + x_{9t}^c &= 750 \\
 x_{5t}^d + x_{7t}^d + x_{8t}^d + x_{9t}^d &= 75 \\
 x_{5t}^e + x_{7t}^e + x_{8t}^e + x_{9t}^e &= 559 \\
 x_{5t}^f + x_{7t}^f + x_{8t}^f + x_{9t}^f &= 40 \\
 x_{5t}^g + x_{7t}^g + x_{8t}^g + x_{9t}^g &= 89 \\
 x_{5t}^h + x_{7t}^h + x_{8t}^h + x_{9t}^h &= 61 \\
 x_{5t}^i + x_{7t}^i + x_{8t}^i + x_{9t}^i &= 52 \\
 x_{5t}^j + x_{7t}^j + x_{8t}^j + x_{9t}^j &= 329
 \end{aligned}$$

In addition, TPR upper bounds for the network model were required.

$$\begin{aligned}
 x_{5t}^a - 8y_{5t} &\leq 0 && \text{(NPS upperbound, CT)} \\
 x_{9t}^a - 8y_{9t} &\leq 0 && \text{(NPS upperbound, MT)} \\
 x_{7t}^a &\leq 0 && \text{(RET upperbound, CT)} \\
 x_{8t}^a &\leq 0 && \text{(RET upperbound, MT)} \\
 \\
 x_{5t}^b - 554y_{5t} &\leq 0 && \text{(NPS upperbound, CT)} \\
 x_{9t}^b - 554y_{9t} &\leq 0 && \text{(NPS upperbound, MT)} \\
 x_{7t}^b &\leq 0 && \text{(RET upperbound, CT)} \\
 x_{8t}^b &\leq 0 && \text{(RET upperbound, MT)} \\
 \\
 x_{5t}^c - 750y_{5t} &\leq 0 && \text{(NPS upperbound, CT)} \\
 x_{9t}^c - 750y_{9t} &\leq 0 && \text{(NPS upperbound, MT)} \\
 x_{7t}^c &\leq 0 && \text{(RET upperbound, CT)} \\
 x_{8t}^c &\leq 0 && \text{(RET upperbound, MT)} \\
 \\
 x_{5t}^d - 75y_{5t} &\leq 0 && \text{(NPS upperbound, CT)} \\
 x_{9t}^d - 75y_{9t} &\leq 0 && \text{(NPS upperbound, MT)} \\
 x_{7t}^d &\leq 0 && \text{(RET upperbound, CT)} \\
 x_{8t}^d &\leq 0 && \text{(RET upperbound, MT)} \\
 \\
 x_{5t}^e - 434y_{5t} &\leq 0 && \text{(NPS upperbound, CT)} \\
 x_{9t}^e - 434y_{9t} &\leq 0 && \text{(NPS upperbound, MT)} \\
 x_{7t}^e - 125y_{7t} &\leq 0 && \text{(RET upperbound, CT)} \\
 x_{8t}^e - 125y_{8t} &\leq 0 && \text{(RET upperbound, MT)} \\
 \\
 x_{5t}^f - 40y_{5t} &\leq 0 && \text{(NPS upperbound, CT)} \\
 x_{9t}^f - 40y_{9t} &\leq 0 && \text{(NPS upperbound, MT)} \\
 x_{7t}^f &\leq 0 && \text{(RET upperbound, CT)} \\
 x_{8t}^f &\leq 0 && \text{(RET upperbound, MT)}
 \end{aligned}$$

$$\begin{array}{llll}
x_{5t}^a - 82y_{5t} \leq 0 & (\text{NPS upperbound, CT}) \\
x_{9t}^a - 82y_{9t} \leq 0 & (\text{NPS upperbound, MT}) \\
x_{7t}^a - 7y_{7t} \leq 0 & (\text{RET upperbound, CT}) \\
x_{8t}^a - 7y_{7t} \leq 0 & (\text{RET upperbound, MT}) \\
\\
x_{5t}^h - 41y_{5t} \leq 0 & (\text{NPS upperbound, CT}) \\
x_{9t}^h - 41y_{9t} \leq 0 & (\text{NPS upperbound, MT}) \\
x_{7t}^h - 20y_{9t} \leq 0 & (\text{RET upperbound, CT}) \\
x_{8t}^h - 20y_{7t} \leq 0 & (\text{RET upperbound, MT}) \\
\\
x_{5t}^i - 22y_{5t} \leq 0 & (\text{NPS upperbound, CT}) \\
x_{9t}^i - 22y_{9t} \leq 0 & (\text{NPS upperbound, MT}) \\
x_{7t}^i - 30y_{9t} \leq 0 & (\text{RET upperbound, CT}) \\
x_{8t}^i - 30y_{7t} \leq 0 & (\text{RET upperbound, MT}) \\
\\
x_{5t}^j - 239y_{5t} \leq 0 & (\text{NPS upperbound, CT}) \\
x_{9t}^j - 239y_{9t} \leq 0 & (\text{NPS upperbound, MT}) \\
x_{7t}^j - 90y_{9t} \leq 0 & (\text{RET upperbound, CT}) \\
x_{8t}^j - 90y_{7t} \leq 0 & (\text{RET upperbound, MT})
\end{array}$$

These constraints also helped drive the zero-one integer variables.

The TPR goal constraints for the G.P. model appear as follows:

$$\begin{array}{ll}
x_{5t}^a + x_{7t}^a + x_{8t}^a + x_{9t}^a + d_{-1} - d_{+1} = 8 \\
x_{5t}^b + x_{7t}^b + x_{8t}^b + x_{9t}^b + d_{-2} - d_{+2} = 554 \\
x_{5t}^c + x_{7t}^c + x_{8t}^c + x_{9t}^c + d_{-3} - d_{+3} = 750 \\
x_{5t}^d + x_{7t}^d + x_{8t}^d + x_{9t}^d + d_{-4} - d_{+4} = 75 \\
x_{5t}^e + x_{7t}^e + x_{8t}^e + x_{9t}^e + d_{-5} - d_{+5} = 559 \\
x_{5t}^f + x_{7t}^f + x_{8t}^f + x_{9t}^f + d_{-6} - d_{+6} = 40 \\
x_{5t}^g + x_{7t}^g + x_{8t}^g + x_{9t}^g + d_{-7} - d_{+7} = 89 \\
x_{5t}^h + x_{7t}^h + x_{8t}^h + x_{9t}^h + d_{-8} - d_{+8} = 61 \\
x_{5t}^i + x_{7t}^i + x_{8t}^i + x_{9t}^i + d_{-9} - d_{+9} = 52 \\
x_{5t}^j + x_{7t}^j + x_{8t}^j + x_{9t}^j + d_{-10} - d_{+10} = 329
\end{array}$$

Upper bound constraints for the goal programming model are:

$$\begin{array}{ll}
x_{5t}^a \leq 8 \\
x_{9t}^a \leq 8 \\
x_{7t}^a \leq 0 \\
x_{8t}^a \leq 0 \\
\\
x_{5t}^b \leq 554 \\
x_{9t}^b \leq 554 \\
x_{7t}^b \leq 0 \\
x_{8t}^b \leq 0
\end{array}$$

$$\begin{aligned}x_{5t}^c &\leq 750 \\x_{9t}^c &\leq 750 \\x_{7t}^c &\leq 0 \\x_{8t}^c &\leq 0\end{aligned}$$

$$\begin{aligned}x_{5t}^d &\leq 75 \\x_{9t}^d &\leq 75 \\x_{7t}^d &\leq 0 \\x_{8t}^d &\leq 0\end{aligned}$$

$$\begin{aligned}x_{5t}^e &\leq 434 \\x_{9t}^e &\leq 434 \\x_{7t}^e &\leq 125 \\x_{8t}^e &\leq 125\end{aligned}$$

$$\begin{aligned}x_{5t}^f &\leq 40 \\x_{9t}^f &\leq 40 \\x_{7t}^f &\leq 0 \\x_{8t}^f &\leq 0\end{aligned}$$

$$\begin{aligned}x_{5t}^g &\leq 82 \\x_{9t}^g &\leq 82 \\x_{7t}^g &\leq 7 \\x_{8t}^g &\leq 7\end{aligned}$$

$$\begin{aligned}x_{5t}^h &\leq 41 \\x_{9t}^h &\leq 41 \\x_{7t}^h &\leq 20 \\x_{8t}^h &\leq 20\end{aligned}$$

$$\begin{aligned}x_{5t}^i &\leq 22 \\x_{9t}^i &\leq 22 \\x_{7t}^i &\leq 30 \\x_{8t}^i &\leq 30\end{aligned}$$

$$\begin{aligned}x_{5t}^j &\leq 239 \\x_{9t}^j &\leq 239 \\x_{7t}^j &\leq 90 \\x_{8t}^j &\leq 90\end{aligned}$$

Attrition Constraints. Constraints dealing with attrition rates include DEP attrition, BMT attrition, course attrition, and the balk rate. The following set of constraints apply:

DEP Attrition:

$$\begin{aligned}-.9x_{12} + x_{23}^a + x_{25}^a + x_{23}^b + x_{25}^b + \dots &= 0 \text{ (network model)} \\-.9x_{12} + x_{23}^a + x_{23}^b + \dots + x_{23}^j + \dots &= 0 \text{ (GP model)}\end{aligned}$$

BMT Attrition (applies to both models):

$$-.93x_{45}^a + x_{5t}^a = 0$$

$$-.93x_{45}^b + x_{5t}^b = 0$$

.

$$-.93x_{45}^j + x_{5t}^j = 0$$

Course Attrition (both models):

$$-.966x_{23}^a + x_{34}^a = 0 \quad (\text{NPS contract training})$$

$$-.966x_{67}^a + x_{7t}^a = 0 \quad (\text{RET contract training})$$

$$-.966x_{59}^a + x_{9t}^a = 0 \quad (\text{NPS military training})$$

$$-.966x_{68}^a + x_{8t}^a = 0 \quad (\text{RET military training})$$

$$-.962x_{23}^b + x_{34}^b = 0 \quad (\text{NPS contract training})$$

$$-.962x_{67}^b + x_{7t}^b = 0 \quad (\text{RET contract training})$$

$$-.962x_{59}^b + x_{9t}^b = 0 \quad (\text{NPS military training})$$

$$-.962x_{68}^b + x_{8t}^b = 0 \quad (\text{RET military training})$$

$$-.986x_{23}^c + x_{34}^c = 0 \quad (\text{NPS contract training})$$

$$-.986x_{67}^c + x_{7t}^c = 0 \quad (\text{RET contract training})$$

$$-.986x_{59}^c + x_{9t}^c = 0 \quad (\text{NPS military training})$$

$$-.986x_{68}^c + x_{8t}^c = 0 \quad (\text{RET military training})$$

$$-.9x_{23}^d + x_{34}^d = 0 \quad (\text{NPS contract training})$$

$$-.9x_{67}^d + x_{7t}^d = 0 \quad (\text{RET contract training})$$

$$-.9x_{59}^d + x_{9t}^d = 0 \quad (\text{NPS military training})$$

$$-.9x_{68}^d + x_{8t}^d = 0 \quad (\text{RET military training})$$

$$-.981x_{23}^e + x_{34}^e = 0 \quad (\text{NPS contract training})$$

$$-.981x_{67}^e + x_{7t}^e = 0 \quad (\text{RET contract training})$$

$$-.981x_{59}^e + x_{9t}^e = 0 \quad (\text{NPS military training})$$

$$-.981x_{68}^e + x_{8t}^e = 0 \quad (\text{RET military training})$$

$$-.989x_{23}^f + x_{34}^f = 0 \quad (\text{NPS contract training})$$

$$-.989x_{67}^f + x_{7t}^f = 0 \quad (\text{RET contract training})$$

$$-.989x_{59}^f + x_{9t}^f = 0 \quad (\text{NPS military training})$$

$$-.989x_{68}^f + x_{8t}^f = 0 \quad (\text{RET military training})$$

$$-.992x_{23}^g + x_{34}^g = 0 \quad (\text{NPS contract training})$$

$$-.992x_{67}^g + x_{7t}^g = 0 \quad (\text{RET contract training})$$

$$-.992x_{59}^g + x_{9t}^g = 0 \quad (\text{NPS military training})$$

$$-.992x_{68}^g + x_{8t}^g = 0 \quad (\text{RET military training})$$

$$-.906x_{23}^h + x_{34}^h = 0 \quad (\text{NPS contract training})$$

$$-.906x_{67}^h + x_{7t}^h = 0 \quad (\text{RET contract training})$$

$$-.906x_{59}^h + x_{9t}^h = 0 \quad (\text{NPS military training})$$

$$-.906x_{68}^h + x_{8t}^h = 0 \quad (\text{RET military training})$$

$$\begin{array}{ll}
-.933x_{23}^i + x_{34}^i = 0 & \text{(NPS contract training)} \\
-.933x_{67}^i + x_{7t}^i = 0 & \text{(RET contract training)} \\
-.933x_{59}^i + x_{9t}^i = 0 & \text{(NPS military training)} \\
-.933x_{68}^i + x_{8t}^i = 0 & \text{(RET military training)} \\
\\
-.962x_{23}^j + x_{34}^j = 0 & \text{(NPS contract training)} \\
-.962x_{67}^j + x_{7t}^j = 0 & \text{(RET contract training)} \\
-.962x_{59}^j + x_{9t}^j = 0 & \text{(NPS military training)} \\
-.962x_{68}^j + x_{8t}^j = 0 & \text{(RET military training)}
\end{array}$$

Balk Rate:

$$\begin{array}{ll}
-br x_{34}^a + x_{45}^a = 0 & \text{where } br = .9 \\
-br x_{34}^b + x_{45}^b = 0 & = .85 \\
. & = .80 \\
. & = .75 \\
. & = .70 \\
-br x_{34}^j + x_{45}^j = 0 & = .65 \\
& = .60 \\
& = .55 \\
& = .50
\end{array}$$

Accession Constraints. The total number of NPS accessions for FY91 is 36,000. The accession limit for the illustrative example was calculated by the percent of the total NPS TPR represented by the example (approximately 7.7%) and finding the appropriate proportion of the total accessions for the example. The following constraint represents the limit on accessions for the network model:

$$x_{45}^a + x_{45}^b + \dots + x_{45}^j - 2774 y_{45} \leq 0$$

The following constraint was used for the goal programming model:

$$x_{45}^a + x_{45}^b + \dots + x_{45}^j \leq 0$$

Switch Constraints. Switch constraints were used in the network model to select the most cost effective path for a commodity to travel. Several rules for setting switches applied:

- 1) A commodity could follow the path of pre-accession

training or the current policy, but not both. The following constraints represent this rule:

$$\begin{aligned} Y_{23} + Y_{25} &= 1 \\ Y_{67} + Y_{68} &= 1 \end{aligned}$$

2) If the "a" switch was set for a particular training policy, all subsequent switches along the chosen path must be set. The following constraints apply:

$$\begin{aligned} Y_{23} - Y_{34} &= 0 \\ Y_{34} - Y_{45} &= 0 \\ Y_{45} - Y_{5t} &= 0 \\ Y_{25} - Y_{59} &= 0 \\ Y_{59} - Y_{9t} &= 0 \\ Y_{67} - Y_{7t} &= 0 \\ Y_{68} - Y_{8t} &= 0 \end{aligned}$$

3) Both NPS and RET entities of the same commodity must be trained under the same policy. The following constraint sets this rule:

$$Y_{25} - Y_{68} = 0$$

In addition to the above switches, a set of constraints drives the remaining zero-one integer variables. The following constraints were used:

$$\begin{aligned} x_{23} - 1.0e^{12} y_{23} &\leq 0 \\ x_{34} - 1.0e^{12} y_{34} &\leq 0 \\ x_{59} - 1.0e^{12} y_{59} &\leq 0 \\ x_{67} - 1.0e^{12} y_{67} &\leq 0 \\ x_{68} - 1.0e^{12} y_{68} &\leq 0 \end{aligned}$$

Objective Function. Two objective functions were formulated following the formulation given in the previous chapter. To find the minimum cost, the following objective function was used in the network model:

$$\begin{aligned}
\text{Min } & 2993x_{12} + 382x_{23}^a + \dots + 382x_{23}^j + c^1x_{34}^a + \dots + c^1x_{34}^j + \\
& 3769x_{5t}^a + \dots + 3769x_{5t}^j + 382x_{67}^a + \dots + 382x_{67}^j + \\
& c^2x_{7t}^a + \dots + c^2x_{7t}^j + 382x_{25}^a + \dots + 382x_{25}^j + 3769x_{59}^a + \\
& \dots + 3769x_{59}^j + c^3x_{9t}^a + \dots + c^3x_{9t}^j + 382x_{68}^a + \dots + \\
& 382x_{68}^j + c^3x_{8t}^a + \dots + c^3x_{8t}^j
\end{aligned}$$

where, c^1 - appropriate cost coefficient from Table 6,
column CT(NPS)

c^2 - appropriate cost coefficient from Table 6,
column CT(RET)

c^3 - appropriate cost coefficient from Table 6,
column MT

The following objective function was used for the goal programming model:

$$\begin{aligned}
\text{Min } & d_1^- + d_1^+ + d_2^- + d_2^+ + d_3^- + d_3^+ + d_4^- + d_4^+ + d_5^- + d_5^+ \\
& + d_6^- + d_6^+ + d_7^- + d_7^+ + d_8^- + d_8^+ + d_9^- + d_9^+ + d_{10}^- + d_{10}^+
\end{aligned}$$

QSB Processing

The QSB software package used for the example is a user friendly optimization package that can solve linear programs with up to 500 constraints and 500 decision variables. The ILP Decision Support System in QSB was used to solve the network. This system solves mixed integer problems using the branch-and-bound method (5). This technique enumerates all feasible solutions, then converges on the optimal solution. Appendix B

presents an example QSB input file. The output from the example is presented in Appendix C. The goal programming model was solved with QSB's LP Decision Support System. This system solves LP's using the well known simplex method. Appendix D presents the QSB input file for the goal programming model. An example of the output is presented in Appendix E.

Results and Analysis

Two models were run for the illustrative example. Initially, the minimum cost network model was run to measure the impact of increasing bask rates to the TPR and training production process. A stipend of \$150 per month and housing allowance of \$300 per month for contract training NPS students was used for the first set of runs. Active duty retrainees continued to receive \$1,300 per month salary if attending contract training. An accession ceiling of 536 NPS enlistees can enter BMT. A summary of results for AFSC 49131 is presented in Table 7, on the following page. The remaining AFSC results are given in Appendix F.

TABLE 7

SUMMARY OF RESULTS FOR EXAMPLE NETWORK MODEL
AT \$450/MONTH SUBSISTENCE ALLOWANCE

<u>AFSC</u>	<u>Rec</u> <u>Req</u>	<u>TT Entrs</u> <u>NPS</u> <u>RET</u>	<u>TT Grads</u> <u>NPS</u> <u>RET</u>	<u>Acc</u>	<u>Trnd</u> <u>NPS</u>	<u>Per</u> <u>RET</u>	<u>Cost</u> <u>(mil)</u>
49131							
10% Balk	588	529 128	519 125	467	434	125	6.8
15% Balk	622	560 128	549 125	467	434	125	7.0
20% Balk	661	595 128	584 125	467	434	125	7.3
*25% Balk	529	443 128	434 125	467	434	125	7.4

* Denotes switch to current training policy from pre-accession

The first column, recruiting requirement, identifies the number of NPS students to be recruited, at the different balk rates, to still achieve the TPR goal. The next two columns show the number of NPS and RET students entering technical training. The accessions column represents the number of NPS enlistees sent to BMT. The next two columns show the number of trained NPS and RET personnel. The final column represents the total cost to meet the TPR goal. The balk rate does not impact the number of prior service retrainees. Accession rates for the current policy are higher than those for the pre-accession policy, but are under the maximum number of accessions allowed. Enlistees in the current policy hit fewer "attrition gates" prior to going to BMT. This information applies to all runs of the network example.

The cost advantage of a pre-accession training policy over the current policy was diminished as the balk rate increased. At a balk rate of 25%, the model selected the current policy over

the pre-accession policy. At a 10% balk rate, an 8.6% savings over the cost of the current policy was realized. A 15% balk rate lowered the savings to 5.1%. A savings of only 1.3% was made at a balk rate of 20%.

In addition, recruiting requirements were impacted by the pre-accession training policy and rising balk rates. An 11.2% increase over recruiting NPS under the current policy was needed under pre-accession policy at a 10% balk rate. When the balk rate was raised to 15%, recruiting requirements rose to 17.6% over current policy needs. At a 20% balk rate, recruiting requirements were 25% higher than current policy requirements.

Table 8 represents the results of the model when the student stipend is raised by \$150 per month to \$300 per month. The remaining AFSC results are presented in Appendix G.

TABLE 8
SUMMARY OF RESULTS FOR EXAMPLE NETWORK MODEL
AT \$600/MONTH SUBSISTENCE ALLOWANCE

<u>AFSC</u>	<u>Rec Req</u>	<u>TT Entrs NPS</u>	<u>RET</u>	<u>TT Grads NPS</u>	<u>RET</u>	<u>Acc</u>	<u>Trnd NPS</u>	<u>Per RET</u>	<u>Cost (mil)</u>
49131									
10% Balk	588	529	128	519	125	467	434	125	6.9
15% Balk	622	560	128	549	125	467	434	125	7.2
*20% Balk	529	443	128	434	125	467	434	125	7.4
* Denotes switch to current training policy from pre-accession									

When the stipend was increased by \$150 per month the model selected the current policy over the pre-accession policy when the balk rate was at 20%. A 6.7% savings over the current policy

was realized when the balk rate was 10%. At a balk rate of 15%, the savings was only 3.2% better. Recruiting requirements remained the same as the previous example.

Table 9 represents all ten AFSCs used in the illustrative example. A \$450 per month subsistence allowance and an accession ceiling of 2775 were used.

TABLE 9
SUMMARY OF RESULTS FOR EXAMPLE NETWORK MODEL
AT \$450/MONTH SUBSISTENCE ALLOWANCE

<u>Balk Rate</u>	<u>Rec Req</u>	<u>TT Entos</u> <u>NPS</u> <u>RET</u>	<u>TT Grads</u> <u>NPS</u> <u>RET</u>	<u>Acc</u>	<u>Trnd Per</u> <u>NPS</u> <u>RET</u>	<u>Cost</u> <u>(mil)</u>
10%	3121	2809 285	2683 272	2414	2245 272	33.4
15%	3305	2974 285	2840 272	2414	2245 272	34.8
20%	3511	3160 285	3018 272	2414	2245 272	36.3
*25%	2809	2351 285	2245 272	2528	2245 272	37.2

* Denotes switch to current training policy from pre-accession

The overall cost savings for the pre-accession training policy is 10.2% better than the current policy when the balk rate was 10%. However, recruiting requirements were 11.1% higher for the pre-accession policy. At a balk rate of 15%, the cost savings dropped to 6.5% while recruiting requirements rose to 17.7%. The savings was only 2.4% at a 20% balk rate while recruiting went up to 25% higher.

Table 10, on the following page, represents the same model run at a \$600 per month subsistence.

TABLE 10

SUMMARY OF RESULTS FOR EXAMPLE NETWORK MODEL
AT \$600/MONTH SUBSISTENCE ALLOWANCE

<u>Balk</u> <u>Rate</u>	<u>Rec</u> <u>Req</u>	<u>TT Entrs</u>		<u>TT Grads</u>		<u>Acc</u>	<u>Trnd Per</u>		<u>Cost</u> <u>(mil)</u>
		<u>NPS</u>	<u>RET</u>	<u>NPS</u>	<u>RET</u>		<u>NPS</u>	<u>RET</u>	
10%	3121	2809	285	2683	272	2414	2245	272	34.3
15%	3305	2974	285	2840	272	2414	2245	272	35.7
*20%	2809	2351	285	2245	272	2528	2245	272	37.2

* Denotes switch to current training policy from pre-accession

The cost savings for this run was 7.9% greater than the current policy at a 10% balk rate. At a 15% balk rate, the savings dropped to 4.1%. The current policy was chosen when the balk rate was at 20%. Recruiting requirements remained the same as the previous model.

The goal programming model was run to identify any deviations in meeting TPR goals under a policy of pre-accession training due to increasing balk rates. Table 11, on the following page, represents a summary of results for AFSC 49131. The remaining AFSCs are presented in Appendix H.

TABLE 11
SUMMARY OF RESULTS FOR EXAMPLE GP MODEL

<u>AFSC</u>	<u>TPR GOAL</u>		<u>TECH TRN</u>		<u>TECH TRN</u>		<u>ACCESS</u>	<u>TRAINED</u>	
	<u>NPS</u>	<u>RET</u>	<u>ENTRIES</u>		<u>GRADS</u>			<u>PERSONNEL</u>	
49313	434	125	<u>NPS</u>	<u>RET</u>	<u>NPS</u>	<u>RET</u>		<u>NPS</u>	<u>RET</u>
BALK RATE									
10%			529	128	519	125	467	434	125
15%			560	128	549	125	467	434	125
20%			595	128	584	125	467	434	125
25%			635	128	623	125	467	434	125
30%			680	128	667	125	467	434	125
35%			732	128	718	125	467	434	125
40%			793	128	778	125	467	434	125
45%			865	128	849	125	467	434	125
50%			952	128	934	125	467	434	125

TPR goals were met at each balk rate. Since the balk rate does not affect RET students, no change in the number of entries and graduates were recorded. While the number of NPS entries to technical training and graduates increased, the rising balk rate before entering BMT prevented the accessions ceiling of 536 NPS enlistees from being exceeded. The only known restrictions on the system are TPR goals for a fiscal year and the number of accessions per fiscal year. Unless restrictions are placed on the number of students recruited and/or allowed to enter technical training in a given fiscal year, the TPR goal would always be met. However, unlimited recruiting to meet TPR goals as the balk rate increased would not be cost effective. The previous network model found the current training policy to be more cost effective if the balk rate became excessively high.

V. Conclusions

This final chapter presents observations about the results of this study. The purpose of this research was to develop a model to aid decision makers in choosing an initial skills training policy. The key results, issues and concerns, and policy implications for management will be discussed.

Key Results

The most important result was that implementing a policy of pre-accession training would be more cost effective than the current policy under certain conditions. The balk rate and subsistence allowance are key factors impacting the savings realized for pre-accession training. Table 12 shows the savings for the ten AFSC's modeled in the previous chapter.

TABLE 12
SUMMARY OF SAVINGS FOR PRE-ACCESSION TRAINING

<u>Balk Rate</u>	<u>Subsistence Allowance</u>	<u>Savings</u>	<u>% Difference</u>
10%	\$450	3.8 million	10.2
15%	\$450	2.4 million	6.5
20%	\$450	.9 million	2.4

10%	\$600	2.9 million	7.9
15%	\$600	1.5 million	4.1

While recruiting levels were found to be higher for the pre-accession policy, as much as 25% higher than the current policy, accession levels were 4.5% lower. Under the pre-accession

policy, enlistees pass through more levels of attrition (DEP, technical training, balk rate) prior to entering BMT than they would for the current policy (DEP only). The pre-accession policy would be more flexible at meeting TPR goals during periods of decreasing accessions.

The network model proved to be a much more realistic approach than the goal programming model in determining the impact of pre-accession training on the TPR process. Both models provided information on recruiting requirements, technical training school entry requirements and the number of graduates, the number of accessions, and the results of meeting TPR goal requirements. In addition, the network model provided data on the total cost of going through the training pipeline. The goal programming model provided information on the number of deviations from TPR goals. However, due to the limited known restrictions placed on the goal programming model, there was never a case where a deviation from a TPR goal existed. The only known restrictions on the model are TPR goals and accession levels. The ceiling on accession levels was high enough to ensure TPR goals were met. Training budget restrictions, recruiting restrictions, or restrictions on the number of students entering technical training could have made the model more meaningful. Without these restrictions, recruiting levels could be raised to counter a rising balk rate and still meet TPR goals.

A potential bottleneck could exist in the model. A

bottleneck could be created if restrictions were placed on the number of classes conducted per fiscal year. In addition, if the number of accessions were reduced too much, TPR goals may not be met. The number of retrainees could be raised to counter this problem. Additionally, increasing the number of retrainees could be effective in countering prohibitive costs associated with rising balk rates or higher recruiting goals.

Issues and Concerns

Several issues and concerns are left unanswered. An optimization approach was used to model the impact of pre-accession training on the TPR process. Issues such as quality of training and "blueness" of training cannot be addressed in such a model. The impact of greater requirements to the recruiting mission cannot be measured with the model (short of the actual cost per additional recruit). An actual test of the policy would be required to accurately measure these issues. Surveys could be conducted to determine the quality of graduates trained by contract against those trained by the military. This method could address the "blueness" questions and quality of training issues. The impact of higher recruiting goals could also be measured.

Policy Implications for Management

The implementation of a pre-accession training policy could hinder management control of the training production process. A flexible contract would have to be established to allow managers

to respond to fluctuations in the TPR. Classes would have to be added or dropped during the fiscal year to reduce under or over production of any AFSC. Management must also be able to respond to rising costs in training. Competitive bidding on training contracts could counter rising costs. Bulk rates must also be controlled to keep the new policy cost effective.

The model developed for this thesis could be used to calculate recruiting goals, establish the required number of classes to meet TPR goals, and estimate a training budget. The model can be adjusted to calculate annual or quarterly figures. It is flexible enough to incorporate changes in TPR goals, accessions, or acquisition costs.

Appendix A: Sample AFSCs and FY91 TPR Goals (7;10)

<u>AFSC</u>	<u>SPEC DESC</u>	<u>COURSE ATTRITION</u>	<u>TOT TPR (TECH)</u>	<u>NPS</u>	<u>RET</u>
23131	Graphics	0.034	8	8	0
25130	Weather	0.096	324	269	55
27630C	Appr Aero C&W	0.011	250	225	25
30430	Appr WB Comm Equip	0.058	172	172	0
30534Q	Elec Comp & SW	0.000	104	104	0
36231	Appr Tele Switch	0.033	132	51	81
36233	Missile Cont Comm	0.000	12	12	0
45233A	Appr F/FB-111 Avion	0.000	19	19	0
45234A	Appr Tact Acft Maint	0.038	554	554	0
45234B	Appr Tact Acft Maint	0.043	330	330	0
45235	Appr Tact Elec-Envir	0.030	192	192	0
45430A	Appr Aero Prop	0.014	750	750	0
45730A	Appr Strat Acft Maint	0.100	75	75	0
45730B	Appr Strat Acft Maint	0.021	117	117	0
45730D	Appr Strat Acft Maint	0.023	38	38	0
45831	Appr Non Dest Insp	0.017	54	54	0
46230F	Acft Arm Sys	0.006	660	660	0
47232	Appr Gen Purp Ven	0.000	198	198	0
49131	Appr Comm-Comp Sys Opr	0.019	559	434	125
49330	Appr Comm-Comp Sys Cost	0.027	296	248	48
54531	Appr Liq Fuels Sys Maint	0.011	40	40	0
55230	Appr Struc Spec	0.013	130	130	0
56630	Appr Pest Mngt	0.000	24	24	0
57130	Fire Protect	0.004	760	760	0
62330	Appr Serv Spec	0.006	367	365	2
67231	Fin Mngt	0.008	89	82	7
75330	Combat Arms	0.034	25	20	5
90330	Radiologic	0.112	175	139	36
90430	Cardiopulm Lab	0.094	61	41	20
90630	Med Admin	0.005	364	294	70
91330	Appr Phys Therap	0.067	52	22	30
98130	Dental Asst	0.038	329	239	90

Appendix B: Example OSB Input File (AFSC 49131)

Input Data Describing Your Problem 49131.10%BR

Page 1

Min	+2993.00X12	+382.000X23	+4550.00X34	X45	+3769.00X5t
	+382.000X67	+6050.00X7t	+382.000X25	+3769.00X59	+7000.00X9t
	+382.000X68	+7000.00X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t		
Subject to					
(1)	X12	X23	X34	X45	+1.00000X5t
	X67	+1.00000X7t	X25	X59	+1.00000X9t
	X68	+1.00000X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	= +559.000	
(2)	-.900000X12	+1.00000X23	X34	X45	X5t
	X67	X7t	+1.00000X25	X59	X9t
	X68	X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(3)	X12	X23	X34	-.930000X45	+1.00000X5t
	X67	X7t	X25	X59	X9t
	X68	X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(4)	X12	X23	X34	X45	X5t

Input Data Describing Your Problem 49131.10%BR

Page 2

(4)	X67	X7t	-.930000X25	+1.00000X59	X9t
	X68	X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(5)	X12	-.981000X23	+1.00000X34	X45	X5t
	X67	X7t	X25	X59	X9t
	X68	X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(6)	X12	X23	X34	X45	X5t
	-.981000X67	+1.00000X7t	X25	X59	X9t
	X68	X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(7)	X12	X23	X34	X45	X5t
	X67	X7t	X25	-.981000X59	+1.00000X9t
	X68	X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(8)	X12	X23	X34	X45	X5t
	X67	X7t	X25	X59	X9t
	-.981000X68	+1.00000X8t	Y23	Y25	Y34

(8)	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(9)	X12	X23	-1.000000X34	+1.000000X45	X5t
	X67	X7t	X25	X59	X9t
	X68	X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(10)	X12	X23	X34	X45	X5t
	X67	X7t	X25	X59	X9t
	X68	X8t	+1.000000Y23	+1.000000Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	= +1.000000	
(11)	X12	X23	X34	X45	X5t
	X67	X7t	X25	X59	X9t
	X68	X8t	+1.000000Y23	Y25	-1.000000Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(12)	X12	X23	X34	X45	X5t
	X67	X7t	X25	X59	X9t
	X68	X8t	Y23	Y25	+1.000000Y34
	-1.000000Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	

(13)	X12	X23	X34	X45	X5t
	X67	X7t	X25	X59	X9t
	X68	X8t	Y23	Y25	Y34
	+1.000000Y45	Y59	-1.000000Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(14)	X12	X23	X34	X45	X5t
	X67	X7t	X25	X59	X9t
	X68	X8t	Y23	+1.000000Y25	Y34
	Y45	-1.000000Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(15)	X12	X23	X34	X45	X5t
	X67	X7t	X25	X59	X9t
	X68	X8t	Y23	Y25	Y34
	Y45	+1.000000Y59	Y5t	Y67	Y68
	Y7t	Y8t	-1.000000Y9t	=	
(16)	X12	X23	X34	X45	X5t
	X67	X7t	X25	X59	X9t
	X68	X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	+1.000000Y67	+1.000000Y68
	Y7t	Y8t	Y9t	= +1.000000	
(17)	X12	X23	X34	X45	X5t
	X67	X7t	X25	X59	X9t

(17)	X68	X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	+1.00000Y67	Y68
	-1.00000Y7t	Y8t	Y9t	=	
(18)	X12	X23	X34	X45	X5t
	X67	X7t	X25	X59	X9t
	X68	X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	+1.00000Y68
	Y7t	-1.00000Y8t	Y9t	=	
(19)	X12	X23	X34	+1.00000X45	X5t
	X67	X7t	X25	X59	X9t
	X68	X8t	Y23	Y25	Y34
	-536.000Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(20)	X12	X23	X34	X45	X5t
	X67	X7t	+1.00000X25	X59	X9t
	X68	X8t	Y23	-536.000Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(21)	X12	X23	X34	X45	+1.00000X5t
	X67	X7t	X25	X59	X9t
	X68	X8t	Y23	Y25	Y34
	Y45	Y59	-434.000Y5t	Y67	Y68

(21)	Y7t	Y8t	Y9t	=	
(22)	X12	X23	X34	X45	X5t
	X67	X7t	X25	X59	+1.00000X9t
	X68	X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	-434.000Y9t	=	
(23)	X12	X23	X34	X45	X5t
	X67	+1.00000X7t	X25	X59	X9t
	X68	X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	-125.000Y7t	Y8t	Y9t	=	
(24)	X12	X23	X34	X45	X5t
	X67	X7t	X25	X59	X9t
	X68	+1.00000X8t	Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	-125.000Y8t	Y9t	=	
(25)	X12	+1.00000X23	X34	X45	X5t
	X57	X7t	X25	X59	X9t
	X68	X8t	-1.0E+12Y23	Y25	Y34
	Y45	Y59	Y5t	Y67	Y68
	Y7t	Y8t	Y9t	=	
(26)	X12	X23	+1.00000X34	X45	X5t

```

(26)  _____ X67 _____ X7t _____ X25 _____ X59 _____ X9t
      _____ X68 _____ X8t _____ Y23 _____ Y25 -1.0E+12Y34
      _____ Y45 _____ Y59 _____ Y5t _____ Y67 _____ Y68
      _____ Y7t _____ Y8t _____ Y9t ≤ _____
(27)  _____ X12 _____ X23 _____ X34 _____ X45 _____ X5t
      _____ X67 _____ X7t _____ X25 +1.000000X59 _____ X9t
      _____ X68 _____ X8t _____ Y23 _____ Y25 _____ Y34
      _____ Y45 -1.0E+12Y59 _____ Y5t _____ Y67 _____ Y68
      _____ Y7t _____ Y8t _____ Y9t ≤ _____
(28)  _____ X12 _____ X23 _____ X34 _____ X45 _____ X5t
      +1.000000X67 _____ X7t _____ X25 _____ X59 _____ X9t
      _____ X68 _____ X8t _____ Y23 _____ Y25 _____ Y34
      _____ Y45 _____ Y59 _____ Y5t -1.0E+12Y67 _____ Y68
      _____ Y7t _____ Y8t _____ Y9t ≤ _____
(29)  _____ X12 _____ X23 _____ X34 _____ X45 _____ X5t
      _____ X67 _____ X7t _____ X25 _____ X59 _____ X9t
      +1.000000X68 _____ X8t _____ Y23 _____ Y25 _____ Y34
      _____ Y45 _____ Y59 _____ Y5t _____ Y67 -1.0E+12Y68
      _____ Y7t _____ Y8t _____ Y9t ≤ _____
(30)  _____ X12 _____ X23 _____ X34 _____ X45 _____ X5t
      _____ X67 _____ X7t _____ X25 _____ X59 _____ X9t
      _____ X68 _____ X8t _____ Y23 +1.000000Y25 _____ Y34

```

```

(30)  _____ Y45 _____ Y59 _____ Y5t _____ Y67 -1.000000Y68
      _____ Y7t _____ Y8t _____ Y9t = _____

```

Input Data Describing Your Problem 49131.10%BR PG 1
 (Default values are continuous with lower bound 0 and no upper bound)

Var. no.	Var.	Integrality (I/C)	Lower bound	Upper bound
1	X12	<C>	<0	> <32000
2	X23	<C>	<0	> <32000
3	X34	<C>	<0	> <32000
4	X45	<C>	<0	> <32000
5	X5t	<C>	<0	> <32000
6	X67	<C>	<0	> <32000
7	X7t	<C>	<0	> <32000
8	X25	<C>	<0	> <32000
9	X59	<C>	<0	> <32000
10	X9t	<C>	<0	> <32000
11	X68	<C>	<0	> <32000
12	X8t	<C>	<0	> <32000
13	Y23	<I>	<0	> <1
14	Y25	<I>	<0	> <1
15	Y34	<I>	<0	> <1
16	Y45	<I>	<0	> <1
17	Y59	<I>	<0	> <1
18	Y5t	<I>	<0	> <1
19	Y67	<I>	<0	> <1
20	Y68	<I>	<0	> <1

Input Data Describing Your Problem 49131.10%BR PG 2
 (Default values are continuous with lower bound 0 and no upper bound)

Var. no.	Var.	Integrality (I/C)	Lower bound	Upper bound
21	Y7t	<I>	<0	> <1
22	Y8t	<I>	<0	> <1
23	Y9t	<I>	<0	> <1

Appendix C: Example OSB Output File (AFSC 49131)

Summary of Results for 49131.10%BR						Page : 1
Variables No. Names	Solution	Obj. Fnctn. Coefficient	Variables No. Names	Solution	Obj. Fnctn. Coefficient	
1 X12	+587.29022	+2993.0002	13 Y23	+1.0000000	0	
2 X23	+528.56116	+382.00000	14 Y25	0	0	
3 X34	+518.51849	+4550.0000	15 Y34	+1.0000000	0	
4 X45	+466.66666	0	16 Y45	+1.0000000	0	
5 X5t	+434.00000	+3769.0000	17 Y59	0	0	
6 X67	+127.42099	+382.00000	18 Y5t	+1.0000000	0	
7 X7t	+125.00000	+6050.0000	19 Y67	+1.0000000	0	
8 X25	0	+382.00000	20 Y68	0	0	
9 X59	0	+3769.0000	21 Y7t	+1.0000000	0	
10 X9t	+1.137E-14	+7000.0000	22 Y8t	0	0	
11 X68	0	+382.00000	23 Y9t	0	0	
12 X8t	+2.842E-15	+7000.0000				
Minimum value of the OBJ = 6759600 Total iterations = 1						

Summary of Results for 49131.15%BR						Page : 1
Variables No. Names	Solution	Obj. Fnctn. Coefficient	Variables No. Names	Solution	Obj. Fnctn. Coefficient	
1 X12	+621.83667	+2993.0002	13 Y23	+1.0000000	0	
2 X23	+559.65295	+382.00000	14 Y25	0	0	
3 X34	+549.01959	+4550.0000	15 Y34	+1.0000000	0	
4 X45	+466.66666	0	16 Y45	+1.0000000	0	
5 X5t	+434.00000	+3769.0000	17 Y59	0	0	
6 X67	+127.42099	+382.00000	18 Y5t	+1.0000000	0	
7 X7t	+125.00000	+6050.0000	19 Y67	+1.0000000	0	
8 X25	0	+382.00000	20 Y68	0	0	
9 X59	0	+3769.0000	21 Y7t	+1.0000000	0	
10 X9t	0	+7000.0000	22 Y8t	0	0	
11 X68	0	+382.00000	23 Y9t	0	0	
12 X8t	0	+7000.0000				
Minimum value of the OBJ = 7013655 Total iterations = 1						

Summary of Results for 49131.25%BR						Page : 1	
Variables No. Names		Solution	Obj. Fnctn. Coefficient	Variables No. Names		Solution	Obj. Fnctn. Coefficient
1	X12	+528.56116	+2993.0002	13	Y23	0	0
2	X23	+3.469E-15	+382.00000	14	Y25	+1.0000000	0
3	X34	+2.776E-15	+4550.0000	15	Y34	0	0
4	X45	0	0	16	Y45	0	0
5	X5t	0	+3769.0000	17	Y59	+1.0000000	0
6	X67	0	+382.00000	18	Y5t	0	0
7	X7t	0	+6050.0000	19	Y67	0	0
8	X25	+475.70505	+382.00000	20	Y68	+1.0000000	0
9	X59	+442.40570	+3769.0000	21	Y7t	0	0
10	X9t	+434.00000	+7000.0000	22	Y8t	+1.0000000	0
11	X68	+127.42099	+382.00000	23	Y9t	+1.0000000	0
12	X8t	+125.00000	+7000.0000				
Minimum value of the OBJ = 7392805 Total iterations = 1							

Summary of Results for 49131.20%BR						Page : 1	
Variables No. Names		Solution	Obj. Fnctn. Coefficient	Variables No. Names		Solution	Obj. Fnctn. Coefficient
1	X12	+660.70142	+2993.0002	13	Y23	+1.0000000	0
2	X23	+594.63123	+382.00000	14	Y25	0	0
3	X34	+583.33325	+4550.0000	15	Y34	+1.0000000	0
4	X45	+466.66666	0	16	Y45	+1.0000000	0
5	X5t	+434.00000	+3769.0000	17	Y59	-5.551E-17	0
6	X67	+127.42099	+382.00000	18	Y5t	+1.0000000	0
7	X7t	+125.00000	+6050.0000	19	Y67	+1.0000000	0
8	X25	-2.842E-14	+382.00000	20	Y68	0	0
9	X59	-1.137E-14	+3769.0000	21	Y7t	+1.0000000	0
10	X9t	0	+7000.0000	22	Y8t	0	0
11	X68	0	+382.00000	23	Y9t	-5.551E-17	0
12	X8t	+2.842E-15	+7000.0000				
Minimum value of the OBJ = 7299466 Total iterations = 1							

Appendix D: Example OSB Input File For TPR
Goal Program (AFSC 49131)

Input Data Describing Your Problem 49131.10%BR Page 1

Min	_____X12	_____X23	_____X34	_____X45	_____X5t	
	_____X67	_____X7t	+1.00000D1M	+1.00000D1F		
Subject to						
(1)	_____X12	_____X23	_____X34	_____X45	+1.00000X5t	
	_____X67	+1.00000X7t	+1.00000D1M	-1.00000D1F	= +559.000	
(2)	-.900000X12	+1.00000X23	_____X34	_____X45	_____X5t	
	_____X67	_____X7t	_____D1M	_____D1F	= _____	
(3)	_____X12	_____X23	_____X34	-.930000X45	+1.00000X5t	
	_____X67	_____X7t	_____D1M	_____D1F	= _____	
(4)	_____X12	-.981000X23	+1.00000X34	_____X45	_____X5t	
	_____X67	_____X7t	_____D1M	_____D1F	= _____	
(5)	_____X12	_____X23	_____X34	_____X45	_____X5t	
	-.981000X67	+1.00000X7t	_____D1M	_____D1F	= _____	
(6)	_____X12	_____X23	-.900000X34	+1.00000X45	_____X5t	
	_____X67	_____X7t	_____D1M	_____D1F	= _____	
(7)	_____X12	_____X23	_____X34	+1.00000X45	_____X5t	
	_____X67	_____X7t	_____D1M	_____D1F	≤ +536.000	
(8)	_____X12	_____X23	_____X34	_____X45	+1.00000X5t	
	_____X67	_____X7t	_____D1M	_____D1F	≤ +404.000	
(9)	_____X12	_____X23	_____X34	_____X45	_____X5t	
	_____X67	+1.00000X7t	_____D1M	_____D1F	≤ +125.000	

Appendix E: Example QSB Output File For TPR
Goal Program (10% Balk Rate)

Summarized Results for TPRGP.10%BR						Page : 1
Variables No. Names	Solution	Opportunity Cost	Variables No. Names	Solution	Opportunity Cost	
1 X1c	+2992.0149	0	16 X34e	+518.51855	0	
2 X23a	+9.8943529	0	17 X34f	+47.789726	0	
3 X23b	+628.03296	0	18 X34g	+97.968941	0	
4 X23c	+908.73027	0	19 X34h	+48.984394	0	
5 X23d	+31.403046	0	20 X34i	+26.284349	0	
6 X23e	+528.56122	0	21 X34j	+285.54361	0	
7 X23f	+48.321259	0	22 X45a	+8.6021509	0	
8 X23g	+98.759010	0	23 X45b	+595.69891	0	
9 X23h	+54.066658	0	24 X45c	+806.45160	0	
10 X23i	+28.171864	0	25 X45d	+25.436466	0	
11 X23j	+296.82288	0	26 X45e	+466.66669	0	
12 X34a	+9.5579453	0	27 X45f	+43.010754	0	
13 X34b	+661.88770	0	28 X45g	+88.172043	0	
14 X34c	+896.05737	0	29 X45h	+44.085953	0	
15 X34d	+28.262741	0	30 X45i	+23.655914	0	
Minimum value of the OBJ = 0 (multiple sols.) Iters. = 62						

Summarized Results for TPRGP.10%BR						Page : 2
Variables No. Names	Solution	Opportunity Cost	Variables No. Names	Solution	Opportunity Cost	
31 X45j	+256.98923	0	46 X67e	+127.42099	0	
32 X5ta	+8.0000000	0	47 X67f	0	0	
33 X5tb	+554.00000	0	48 X67g	+7.0564513	0	
34 X5tc	+750.00000	0	49 X67h	+22.075054	0	
35 X5td	+75.000000	0	50 X67i	+32.154343	0	
36 X5te	+434.00000	0	51 X67j	+93.555092	0	
37 X5tf	+40.000000	0	52 X7ta	0	0	
38 X5tg	+82.000000	0	53 X7tb	0	0	
39 X5th	+40.999935	0	54 X7tc	0	0	
40 X5ti	+22.000000	0	55 X7td	0	0	
41 X5tj	+239.00000	0	56 X7te	+125.00000	0	
42 X67a	0	0	57 X7tf	0	0	
43 X67b	0	0	58 X7tg	+7.0000000	0	
44 X67c	0	0	59 X7th	+20.000000	0	
45 X67d	0	0	60 X7ti	+30.000000	0	
Minimum value of the OBJ = 0 (multiple sols.) Iters. = 62						

Variables No. Names	Solution	Opportunity Cost	Variables No. Names	Solution	Opportunity Cost
61 X7tj	+90.000000	0	76 D8M	0	+1.0000000
62 D1M	0	+1.0000000	77 D8F	0	+1.0000000
63 D1P	0	+1.0000000	78 D9M	0	+1.0000000
64 D2M	0	+1.0000000	79 D9P	0	+1.0000000
65 D2P	0	+1.0000000	80 D10M	0	+1.0000000
66 D3M	0	+1.0000000	81 D10P	0	+1.0000000
67 D3P	0	+1.0000000	82 A1	0	0
68 D4M	0	+1.0000000	83 A2	0	0
69 D4P	0	+1.0000000	84 A3	0	0
70 D5M	0	+1.0000000	85 A4	0	0
71 D5P	0	+1.0000000	86 A5	0	0
72 D6M	0	+1.0000000	87 A6	0	0
73 D6P	0	+1.0000000	88 A7	0	0
74 D7M	0	+1.0000000	89 A8	0	0
75 D7P	0	+1.0000000	90 A9	0	0

Minimum value of the OBJ = 0 (multiple sols.) Iters. = 62

Variables No. Names	Solution	Opportunity Cost	Variables No. Names	Solution	Opportunity Cost
91 A10	0	0	106 A25	0	0
92 A11	0	0	107 A26	0	0
93 A12	0	0	108 A27	0	0
94 A13	0	0	109 A28	0	0
95 A14	0	0	110 A29	0	0
96 A15	0	0	111 A30	0	0
97 A16	0	0	112 A31	0	0
98 A17	0	0	113 A32	0	0
99 A18	0	0	114 A33	0	0
100 A19	0	0	115 A34	0	0
101 A20	0	0	116 A35	0	0
102 A21	0	0	117 A36	0	0
103 A22	0	0	118 A37	0	0
104 A23	0	0	119 A38	0	0
105 A24	0	0	120 A39	0	0

Minimum value of the OBJ = 0 (multiple sols.) Iters. = 62

Variables No. Names	Solution	Opportunity Cost	Variables No. Names	Solution	Opportunity Cost
121 A40	0	0	133 S52	0	0
122 A41	0	0	134 S53	0	0
123 A42	0	0	135 S54	0	0
124 S43	+415.23019	0	136 S55	0	0
125 S44	0	0	137 S56	0	0
126 S45	0	0	138 S57	0	0
127 S46	0	0	139 S58	0	0
128 S47	0	0	140 S59	0	0
129 S48	0	0	141 S60	0	0
130 S49	0	0	142 S61	0	0
131 S50	0	0	143 S62	0	0
132 S51	+.00006340	0	144 S63	0	0
Minimum value of the OBJ = 0 (multiple sols.) Iters. = 62					

Appendix F: Results of Network Model at \$450/Month Subsistence

<u>AFSC</u>	<u>Rec Req</u>	<u>TT Entrs NPS</u>	<u>RET</u>	<u>TT Grads NPS</u>	<u>RET</u>	<u>Acc</u>	<u>Trnd NPS</u>	<u>Per RET</u>	<u>Cost</u>
23131									
Balk Rate									
10%	11	10	0	10	0	9	8	0	114,148
15%	12	11	0	11	0	9	8	0	119,089
20%	13	12	0	11	0	9	8	0	124,647
*25%	10	9	0	8	0	9	8	0	129,429
45234A									
Balk Rate									
10%	765	688	0	662	0	596	554	0	7,673,702
15%	810	729	0	701	0	596	554	0	8,002,271
20%	860	774	0	745	0	596	554	0	8,371,911
*25%	688	576	0	554	0	620	554	0	8,410,813
45430A									
Balk Rate									
10%	1010	909	0	896	0	807	750	0	10,452,380
15%	1070	963	0	949	0	807	750	0	10,900,940
20%	1136	1023	0	1008	0	807	750	0	11,405,580
*25%	910	761	0	750	0	818	750	0	11,599,300
45730A									
Balk Rate									
10%	111	100	0	90	0	81	75	0	1,062,649
15%	118	106	0	95	0	81	75	0	1,108,529
20%	125	112	0	101	0	81	75	0	1,160,145
*25%	100	84	0	75	0	90	75	0	1,180,302
54531									
Balk Rate									
10%	54	49	0	48	0	43	40	0	547,357
15%	57	52	0	51	0	43	40	0	570,686
*20%	49	41	0	40	0	44	40	0	593,675
67231									
Balk Rate									
10%	110	99	7	98	7	89	82	7	1,192,619
15%	117	105	7	104	7	89	82	7	1,241,666
20%	124	112	7	111	7	89	82	7	1,296,854
*25%	99	83	7	82	7	89	82	7	1,324,635

<u>AFSC</u>	<u>Rec</u> <u>Req</u>	<u>TT Entrs</u> <u>NPS</u> <u>RET</u>	<u>TT Grads</u> <u>NPS</u> <u>RET</u>	<u>Acc</u>	<u>Trnd</u> <u>NPS</u>	<u>Per</u> <u>RET</u>	<u>Cost</u>
90430							
	Balk Rate						
10%	60	54 22	49 20	44	41	20	749,890
15%	64	58 22	52 20	44	41	20	775,945
20%	68	61 22	56 20	44	41	20	805,256
25%	72	65 22	59 20	44	41	20	838,476
*30%	54	46 22	41 20	49	41	20	856,554
91330							
	Balk Rate						
10%	32	29 33	27 30	24	22	30	524,000
15%	34	30 33	28 30	24	22	30	537,489
20%	36	32 33	30 30	24	22	30	552,663
25%	38	34 33	32 30	24	22	30	569,860
30%	41	37 33	34 30	24	22	30	589,515
*35%	29	24 33	22 30	26	22	30	590,359
98130							
	Balk Rate						
10%	330	297 94	286 90	257	239	90	3,991,849
15%	350	315 94	303 90	257	239	90	4,136,367
20%	371	334 94	322 90	257	239	90	4,298,951
*25%	297	249 94	239 90	268	239	90	4,462,950

* Denotes switch to current policy

Appendix G: Results of Network Model at \$600/Month Subsistence

<u>AFSC</u>	<u>Rec</u> <u>Req</u>	<u>TT Entrs</u> <u>NPS</u> <u>RET</u>	<u>TT Grads</u> <u>NPS</u> <u>RET</u>	<u>Acc</u>	<u>Trnd</u> <u>NPS</u>	<u>Per</u> <u>RET</u>	<u>Cost</u>
23131							
Balk Rate							
10%	11	10 0	10 0	9	8	0	117,875
15%	12	11 0	11 0	9	8	0	123,036
20%	13	12 0	11 0	9	8	0	128,841
*25%	10	9 0	8 0	9	8	0	129,429
45234A							
Balk Rate							
10%	765	688 0	662 0	596	554	0	7,859,030
15%	810	729 0	701 0	596	554	0	8,198,501
*20%	688	576 0	554 0	620	554	0	8,410,813
45430A							
Balk Rate							
10%	1010	909 0	896 0	807	750	0	10,757,040
15%	1070	963 0	949 0	807	750	0	11,223,520
*20%	910	761 0	750 0	818	750	0	11,599,300
45730A							
Balk Rate							
10%	111	100 0	90 0	81	75	0	1,087,738
15%	118	106 0	95 0	81	75	0	1,135,095
*20%	100	84 0	75 0	90	75	0	1,180,302
54531							
Balk Rate							
10%	54	49 0	48 0	43	40	0	547,357
15%	57	52 0	51 0	43	40	0	570,686
*20%	49	41 0	40 0	44	40	0	593,675
67231							
Balk Rate							
10%	110	99 7	98 7	89	82	7	1,225,929
15%	117	105 7	104 7	89	82	7	1,276,935
*20%	99	83 7	82 7	89	82	7	1,324,635
90430							
Balk Rate							
10%	60	54 22	49 20	44	41	20	768,994
15%	64	58 22	52 20	44	41	20	796,173
20%	68	61 22	56 20	44	41	20	826,748
*25%	54	46 22	41 20	49	41	20	856,554

<u>AFSC</u>	<u>Rec</u> <u>Reg</u>	<u>TT Entrs</u> <u>NPS</u> <u>RET</u>	<u>TT Grads</u> <u>NPS</u> <u>RET</u>	<u>Acc</u>	<u>Trnd</u> <u>NPS</u>	<u>Per</u> <u>RET</u>	<u>Cost</u>
91330							
Balk Rate							
10%	32	29 33	27 30	24	22	30	532,937
15%	34	30 33	28 30	24	22	30	546,951
20%	36	32 33	30 30	24	22	30	562,717
25%	38	34 33	32 30	24	22	30	580,584
*30%	29	24 33	22 30	26	22	30	590,359

98130							
Balk Rate							
10%	330	297 94	286 90	257	239	90	4,088,933
15%	350	315 94	303 90	257	239	90	4,239,163
20%	371	334 94	322 90	257	239	90	4,408,171
*25%	297	249 94	239 90	268	239	90	4,462,950

* Denotes switch to current policy

Appendix H: Results of Goal Programming Model

<u>AFSC</u>	<u>TPR</u>	<u>Goal</u>	<u>TT Entries</u>		<u>TT Grads</u>		<u>Acc</u>	<u>Trnd</u>	<u>Pers</u>
	<u>NPS</u>	<u>RET</u>	<u>NPS</u>	<u>RET</u>	<u>NPS</u>	<u>RET</u>		<u>NPS</u>	<u>RET</u>
23131	8	0							
Balk %									
10			10	0	10	0	9	8	0
15			11	0	11	0	9	8	0
20			12	0	11	0	9	8	0
25			12	0	12	0	9	8	0
30			13	0	13	0	9	8	0
35			14	0	14	0	9	8	0
40			15	0	15	0	9	8	0
45			17	0	16	0	9	8	0
50			18	0	18	0	9	8	0
45234A	554	0							
Balk %									
10			688	0	662	0	596	554	0
15			729	0	701	0	596	554	0
20			774	0	745	0	596	554	0
25			826	0	795	0	596	554	0
30			885	0	851	0	596	554	0
35			953	0	917	0	596	554	0
40			1032	0	993	0	596	554	0
45			1126	0	1083	0	596	554	0
50			1239	0	1192	0	596	554	0
45430A	750	0							
Balk %									
10			909	0	896	0	807	750	0
15			963	0	949	0	807	750	0
20			1023	0	1008	0	807	750	0
25			1096	0	1076	0	807	750	0
30			1169	0	1152	0	807	750	0
35			1259	0	1241	0	807	750	0
40			1364	0	1344	0	807	750	0
45			1487	0	1467	0	807	750	0
50			1636	0	1613	0	807	750	0

45730A	75	0						
Balk %								
10		100	0	90	0	81	75	0
15		106	0	95	0	81	75	0
20		112	0	101	0	81	75	0
25		120	0	108	0	81	75	0
30		128	0	116	0	81	75	0
35		138	0	124	0	81	75	0
40		150	0	135	0	81	75	0
45		163	0	147	0	81	75	0
50		180	0	162	0	81	75	0

54531	40	0						
Balk %								
10		49	0	48	0	43	40	0
15		52	0	51	0	43	40	0
20		55	0	54	0	43	40	0
25		58	0	58	0	43	40	0
30		63	0	62	0	43	40	0
35		67	0	67	0	43	40	0
40		73	0	72	0	43	40	0
45		79	0	79	0	43	40	0
50		87	0	86	0	43	40	0

67231	82	7						
Balk %								
10		99	7	98	7	89	82	7
15		105	7	104	7	89	82	7
20		112	7	111	7	89	82	7
25		119	7	118	7	89	82	7
30		127	7	126	7	89	82	7
35		137	7	136	7	89	82	7
40		149	7	147	7	89	82	7
45		162	7	161	7	89	82	7
50		178	7	177	7	89	82	7

90430	41	20						
Balk %								
10		54	22	49	20	44	41	20
15		58	22	52	20	44	41	20
20		61	22	56	20	44	41	20
25		65	22	59	20	44	41	20
30		70	22	63	20	44	41	20
35		75	22	68	20	44	41	20
40		81	22	74	20	44	41	20
45		89	22	81	20	44	41	20
50		98	22	89	20	44	41	20

91330 22 30

Balk %

10	29	33	27	30	24	22	30
15	30	33	28	30	24	22	30
20	32	33	30	30	24	22	30
25	34	33	32	30	24	22	30
30	37	33	34	30	24	22	30
35	39	33	37	30	24	22	30
40	43	33	40	30	24	22	30
45	46	33	43	30	24	22	30
50	51	33	48	30	24	22	30

98130 239 90

Balk %

10	297	94	286	90	257	239	90
15	315	94	303	90	257	239	90
20	334	94	322	90	257	239	90
25	357	94	343	90	257	239	90
30	382	94	368	90	257	239	90
35	411	94	396	90	257	239	90
40	446	94	429	90	257	239	90
45	486	94	468	90	257	239	90
50	535	94	514	90	257	239	90

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Vita

Captain William J. Beveridge was born on 29 January 1959 in Bitburg, Germany. He graduated from Shadyside High School in 1977 and enlisted in the Air Force. He entered the University of Colorado under the Airmans Commissioning Scholarship Program in 1979. He received a Bachelor of Arts degree in Mathematics and was commissioned in 1983. From 1983 to 1989 he served as a computer systems analyst, chief of the Electronic Intelligence Support Branch, and Test Director for HQ SAC's Intelligence Data Handling Systems at Offutt AFB, Nebraska. He entered the School of Engineering, Air Force Institute of Technology, in August 1989.

Permanent address: 585 Salva Ave
Shadyside, Ohio 43947